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STATISTICAL CHARACTERIZATION OF RUGGED PROPAGATION PATHS WITH APPLICATION TO Rg SCATTERING STUDY

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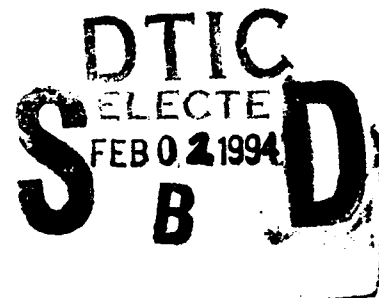
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SUMMARY

The primary objective of this project is to develop and apply improved statistical methodologies for nuclear monitoring. During the past two years, our major efforts have been

[A] Measure the teleseismic P -wave magnitudes of historical Soviet explosions as well as explosions from other foreign test sites recorded at the optimal distance range from 20° to 95° .

[B] Perform various statistical analyses of the raw mb and obtain the optimal network mb values. Conduct the maximum-likelihood magnitude-yield regressions and analyze the source-depth scaling relationship.

[C] Conduct a theoretical study to investigate relevant issues. Improve and document the statistical as well as the forward-modeling tools currently in use.

This semi-annual report summarizes our results obtained under Task [C] during the period September 20, 1993, through November 5, 1993.

An accurate prediction of the regional phases due to explosion sources in areas of high proliferation concern requires a decent understanding of the attenuation/scattering mechanisms along the propagation paths. Motivated by many observations of correlation between the free-surface topography and the coda generation at teleseismic and regional distances, seven simple statistics have been presented and analyzed in this study to test whether they can fully characterize the roughness of an arbitrary rugged free-surface topography. The definitions of these parameters are very natural, and some of parameters might be suitable to quantify the roughness of realistic profiles. The normalized arc length and *Durbin-Watson number* (*von Neumann ratio*) are identified as the best and the poorest, respectively, roughness measures, in terms of correlating with the propagation behavior of R_g (see Figures 95-102 for the regressions). 2-dimensional finite-difference simulations are then conducted to investigate short-period Rayleigh wave scattering by these 27 topographic profiles. The numerical experiments show that rougher topography causes stronger attenuation (as expected), that reflection is an efficient process, and that the bulk of the energy which is not transmitted across the topography is either converted to body waves or reflected back. The scattered P and S waves are radiated as coda to teleseismic distances and some P -SV energy is trapped in the crustal waveguide as P_g , S_g , and L_g . The body waves appear to radiate from the changes in slope and to first order can be visualized as from point diffractors along the rugged free-surface. For most models tested in this study, the R_g -to- S conversion is more efficient than that of R_g -to- P (see Figures 103-129). Particle motion plots of the scattered bodywaves can help to illustrate this point too (see Figure 130-156). The displacement synthetics of the scattered bodywaves, which makes the synthetics can be compared easily. This approach is more convenient than another one which presents the scattered wavefield in strain units. The spatial Q values associated with rough topographic profiles, inferred from the logarithm of the transmitted power spectrum, range from 15 to 80, which are in excellent agreement with the Q_p of the uppermost crust in many places of the world. Regression results also suggest that both the attenuation coefficient, γ , and the scattering loss can be represented as linear functions of the roughness parameters. This work offers a promising approach to quantify effects of scattering by topography and heterogeneity upon other regional phases.

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1. INTRODUCTION

The problem of short-period fundamental-mode Rayleigh waves (or R_g) scattered by topography is important and interesting for many reasons. A significant fraction of the elastic energy generated by a shallow explosion is contained in short-period Rayleigh waves. These short-period Rayleigh waves are the largest phase on the near-source seismogram. However, very often they are attenuated rather rapidly with spatial Q 's at 1 Hz in the range of 20 to 200. Such attenuation can be due to intrinsic shear attenuation in the near surface, or it can be accomplished by scattering from shallow heterogeneity and topography. If the energy is scattered then it must be observed as coda in the near-source, regional, and/or teleseismic seismogram.

The scattering of short-period Rayleigh waves by topography has been proposed as a mechanism for the generation of teleseismic P coda by Greenfield (1971). Gupta and Blandford (1987) (and Gupta and Wagner, 1992) propose that such P coda may be diagnostic of the near source medium. The ability of using teleseismic complexity for discriminating explosions from earthquakes can be accounted for by an explanation that the emergent earthquake teleseismic coda is comprised of pP and of S -to- P conversions at relatively sharp interfaces, whereas the emergent explosion coda is comprised of R_g -to- P conversions. Thus the coda in emergent explosion signals would have more of a "rolling" character which can be distinguished from the "impulsive" coda of emergent earthquakes (Blandford, 1993). Adushkin *et al.* (1990) find R_g from Soviet's Semipalatinsk nuclear test site a very stable yield estimator. With the focus of nuclear monitoring research moving from the yield estimation to seismic event identification, an assessment needs to be made of the maximum range at which R_g could be used to discriminate small events in various geologic/tectonic environments (DARPA, 1992). P coda observed at arrays is often partly composed of Rayleigh waves generated by P waves steeply incident upon shallow heterogeneity or topography. Key (1967 and 1968) identified such Rayleigh waves within the P coda at the EKA array (Eskdalemuir, Scotland) for certain azimuths of arrival. Dainty (1986) shows by use of frequency-wavenumber analysis that P coda at the small NORESS array (southern Norway) is often composed of fundamental short-period Rayleigh waves. Both the coherency of such coda and its persistence are closely related to the scattering of the Rayleigh waves by topography and shallow heterogeneity. Aki and Chouet (1975) proposed three simple models for the generation and propagation of short-period coda from local earthquakes. They considered the case of scattered surface waves as well as scattered body waves. Although the coda of local earthquakes appears to be dominated by S waves, it is clear that trapped modes and surface waves are also present (Phillips and Aki, 1986). A portion of the regional L_g phase and its coda is composed of fundamental and higher mode Rayleigh waves trapped in the crustal waveguide. Der *et al.* (1984) propose that a significant portion of the L_g coda is composed of short-period fundamental Rayleigh waves that concentrate energy near the surface and are multiply scattered, contributing to the long L_g coda observed on regional seismograms. Baumgardt (1990) proposes that L_g from Eastern Kazakh incident upon the Urals produces observable teleseismic P coda at NORSAR. All of these problems have in common a need to estimate the effects of scattering on short-period surface waves due to shallow heterogeneity and topography.

Topographic scattering through a right-angle step was addressed by deBremaecker (1958) and continues as a topic of interest. Numerous workers have examined the incident Rayleigh or Love wave upon welded quarter spaces (see for example, Mal and Knopoff, 1965; McGarr and Alsop, 1967; Drake, 1972; Munasinghe and Farnell, 1973; Tuan and Li, 1974; Martel *et al.*, 1977; Sabina and Willis, 1977; Chen and Alsop, 1979; Fuyuki and Matsumoto, 1980; Drake and Bolt, 1980; Momoi, 1985; Fuyuki and Nakano, 1984; Wojcik and Mak, 1985; and Nakano *et al.*, 1988). Ultrasonic modeling was used by Bullitt and Toksoz (1985) and Toksoz *et al.* (1986) to examine the obliquely incident Rayleigh wave transmission and reflection by sloping topography.

Most previous research concerned with the scattering of Rayleigh waves has dealt with the simplest geometric configurations (quarter-space, three-quarter space, a trench or a vertical step) where the boundaries are always parallel or perpendicular to the grid axis. The present study concentrates on more general topographic profiles, as a follow-up of our previous study summarized in McLaughlin and Jih (1986 and 1987). Linear Finite-Difference (LFD) modeling is chosen simply out of convenience. The method has the advantages that the solution contains all conversions (P - SV , SV - P) and all orders of multiple scattering. We use the 2nd-order formulation of Kelley *et al.* (1976) with absorbing boundary conditions described by Clayton and Engquist (1977) and 1st-order free-surface boundary conditions for topographic surfaces described by Jih *et al.* (1988) and Jih (1993a). The method permits examination of fairly general 2-D models. Surface waves are introduced as initial conditions within the half-space grid. There is now a considerable body of work covering many aspects of scattering using 2-D LFD methods.

McLaughlin and Jih (1987) examined the interaction of incident Rayleigh waves upon a 2-D shallow heterogeneous layer of various thicknesses, scale lengths, and rms velocity fluctuations embedded in a homogeneous half space using 2-dimensional LFD. In this paper, we explore the stability of planar Rayleigh waves incident upon 2-D topography using the same method of analysis. The goal is to determine some basic quantities such as scattering strength, conversion efficiency, and backscattering strength of the topographic relief. These quantities are needed in order to compose models for coda observed near the surface of the Earth. Although the present study tackles the same problem as was treated in our previous work (McLaughlin and Jih, 1986) (hereafter [1]), there are several fundamental improvements. No clear (*i.e.*, quantitative) relationship between the roughness measures and the propagation characteristics was found in [1], because the rough topographic profiles used in [1] did not cover a wide range of profile types. The scattered body waves were described in non-directional strain in [1], which made the synthetics more difficult for direct comparison. In the present work, more roughness measures are tested with a suite of realistic profiles. Furthermore, the scattered body waves are presented in the same displacement unit, with direction of each ray clearly identified.

We first examine the problem of transmission and the partitioning of energy by the scattering process. It is demonstrated as expected that rougher topography produces larger attenuation. Reflection (backscattering) is observed to be an efficient process for all cases examined. In this way the rough topography is characterized by a spatial Q and several other roughness statistics. We use the converted body wave field at depth in the half-space as a measure of the simulated far-field P and S coda.

Attenuation of the short-period Rayleigh wave is found to be strong by moderately rough topography, and Rayleigh-to-body wave conversion is seen to dominate the attenuation process. Examination of the converted body wave field in the half-space leads us to conclude that a significant fraction of the converted SV energy will be trapped in the crust as L_g .

2. ROUGHNESS STATISTICS

2.1 Generation of Random Topography

In this study, it is assumed that the rough topography can be approximated by level elevations separated by sections of 45° slope. Topographic profiles are generated with a random number generator which produces a Markov sequence of values 0, 1, and -1, according to an arbitrarily assigned probability of the "state" 1, hereafter denoted as $Pr[1]$. We assume $0 < Pr[-1] = Pr[1] < 0.5$ and $Pr[0] = 1 - Pr[1] - Pr[-1]$. The sequence of 0, 1 and -1 is regarded as the successive elevation change in the topography. That is, the integral of this Markov sequence represents a profile suitable for forward modeling experiments. Larger $Pr[1]$ would cause more frequent elevation changes in the resulting topographic profile, and hence it is an indication of rougher topography. In this study, both smooth and extremely rugged topography are examined, with $Pr[1]$ ranging from 5% to 35%. Initially, the values 1 and -1 are assumed to have the same probability. Nevertheless, the selection of the current "state" of the Markov chain is governed not only by the preset probability but also by the previous state. For instance, given a previous value of 1, the current value can only be 0 or 1. This Markov condition is imposed to make sure that the topography, as a piecewise-linear polygon, has at least two subsegments of the same slope in each of its linear segment, and to prevent the occurrence of sudden changes such as from 1 to -1 and *vice versa*.

27 rough topographic profiles thus generated were inserted into the grid with flat ground concatenated on both sides. Figure 1 through 9 show the rugged profile, $H(x)$, of the 27 models on the left, log-amplitude wavenumber spectra of the topography in the center, and several corresponding roughness statistics (which are to be defined in the following section) listed on the right of topographic profiles numbered 11 through 73. Only the rugged portion of each profile is shown. In all these models, the rugged portion has a lateral span, X , approximately 30 km.

2.2 Definition of Various Roughness Measures

In searching for quantitative measures to characterize the roughness of a topographic profile, one would expect to seek parameters which are easy to compute once the profile is digitized. Note that each discretized profile is just a time series of equal spatial spacing in the lateral direction, and therefore many techniques used in time series analysis might be suitable for our need. Several statistics which appear to be natural candidates of the roughness measure are defined and tested in this study.

The "normalized total variation", Ω_1 , is defined as $\Omega_1 \equiv \sum |H_i - H_{i-1}|/X$ where H_i is the elevation (in km) at the i th column of the nontrivial portion of the topography. This statistic reflects the idea that in a smooth time series the differences between successive points are all small, and hence the numerator will be small. The denominator is simply a scaling factor. Ω_1 is nothing but the "normalized L^1 norm" of the elevation change. This parameter turns out to be equivalent to the total "probability of elevation change" of the topographic profile. Another roughness measure, which is very similar to Ω_1 , is the "normalized L^2 norm" of the elevation change, Ω_2 , defined as $\sqrt{\sum (H_i - H_{i-1})^2}/X$. When each elevation change

is limited to have at most one unit step (as in all the examples used in this study), Ω_2 is equivalent to Ω_1 (up to a constant). This is not true in the more general case, and hence both quantities ought to be tested. The "Root-mean-squared elevation", Ω_3 , is defined as $\sqrt{\sum (H_i - \bar{H})^2 / N}$ with $\bar{H}$ the average elevation of the topography, and N the number of subintervals. $\Omega_4 \equiv \sum (H_i - H_{i-1})^2 / \sum (H_i - \bar{H})^2$, is also called the "Durbin-Watson statistic" or the "von Neumann ratio" (cf. Bloomfield, 1975). The peak wavenumber spectrum, $K(0)$, is denoted as Ω_5 . The "number of slope changes per unit length" (i.e., the average number of corners per km) is denoted as Ω_6 . Note that Ω_6 is directly proportional to the "probability of slope change", whereas Ω_1 reflects the "probability of elevation change". In calculus terms, Ω_1 and Ω_6 are closely related to the first and second spatial derivatives, respectively, of the topographic profile, H . Ω_5 , the peak wavenumber spectrum $K(0)$, is a measure of the mean elevation, $\bar{H}$, whereas Ω_3 is a measure of the deviation from the mean. The arc length (normalized by the total span), Ω_7 , is computed as $\sum \sqrt{(\Delta X)^2 + (H_i - H_{i-1})^2} / X$ where ΔX is the spacing (in km) in the horizontal direction. For a flat profile, Ω_7 equals to 1. There exist simple relationships among some of the roughness measures. For instance,

$$\Omega_2 = \sqrt{\Delta Z \cdot \Omega_1 / X} ; \text{ and } \Omega_4 = N \cdot (\Delta X \cdot \Omega_2 / \Omega_3)^2.$$

Table 1 lists various roughness measures of 27 profiles numbered from 11 to 73 with increasing $Pr[1]$. In each case, the random number generator is initialized with the seed number being the truncated system clock time at the time the profile was generated. These seed numbers are also included in Table 1, and hence all the profiles can be duplicated on SUN4 computers. The preset probability of state 1 varies from 5% (models 11 through 13) to 35% (models 71 through 73). Larger $Pr[1]$ yields more frequent recurrence of states 1 and -1, which means more elevation variations and hence a rougher topography. Intuitively any arbitrary sequence of 0, 1, -1 should suffice to generate a corresponding random profile. In our LFD calculations, however, the profile needs to be sampled well enough so that each segment consists of at least two subintervals with the same slope. As a result, the "actual" probability of states 1 and -1 is slightly smaller than that of the input. It is interesting to note that Ω_1 happens to represent the "actual" probability of states 1 and -1 combined, which is slightly smaller than twice that of $Pr[1]$. Most statistics as defined above show an increasing trend with the increasing $Pr[1]$, except Ω_4 which seems to exhibit no clear pattern at all.

Table 1. Roughness Statistics of 27 Topographic Profiles									
Model	Ω_1	Ω_2	Ω_3	Ω_4	Ω_5	Ω_6	Ω_7	Pr[1]	Seed
11	0.091	0.0178	0.215	0.0198	0.240	0.839	1.038	0.050	22887
12	0.097	0.0186	0.487	0.0041	0.511	1.004	1.040	0.050	22892
13	0.097	0.0190	0.218	0.0203	0.260	0.967	1.040	0.050	85995
14	0.146	0.0225	0.234	0.0266	0.266	1.389	1.060	0.070	91333
15	0.144	0.0228	0.209	0.0329	0.310	1.439	1.060	0.070	91350
16	0.127	0.0218	0.265	0.0181	0.209	1.194	1.053	0.070	91285
21	0.180	0.0245	0.686	0.0038	0.528	1.600	1.075	0.100	93337
22	0.182	0.0248	0.557	0.0059	0.638	1.757	1.076	0.100	93347
23	0.150	0.0231	0.435	0.0079	0.370	1.429	1.062	0.100	93356
31	0.310	0.0323	1.329	0.0018	0.981	2.357	1.128	0.150	748546615
32	0.230	0.0283	0.234	0.0421	0.317	1.742	1.095	0.150	20333
33	0.233	0.0282	0.408	0.0140	0.303	2.192	1.096	0.150	86016
41	0.283	0.0309	0.756	0.0049	0.599	2.357	1.117	0.200	93397
42	0.298	0.0318	0.878	0.0039	0.751	2.508	1.124	0.200	93407
43	0.316	0.0324	0.751	0.0056	0.819	2.392	1.131	0.200	12345
51	0.401	0.0366	0.469	0.0183	0.584	2.609	1.166	0.250	21691
52	0.361	0.0348	0.553	0.0118	0.549	2.742	1.150	0.250	21696
53	0.399	0.0364	0.506	0.0156	0.633	2.591	1.165	0.250	86037
61	0.478	0.0400	1.003	0.0048	1.741	2.676	1.198	0.300	93459
62	0.437	0.0386	1.160	0.0032	1.153	2.662	1.181	0.300	93468
63	0.438	0.0383	0.745	0.0079	1.112	2.274	1.181	0.300	93479
64	0.477	0.0400	0.539	0.0164	0.663	2.685	1.197	0.320	55473
65	0.483	0.0405	0.934	0.0055	1.207	2.585	1.200	0.320	55499
66	0.512	0.0421	0.604	0.0140	0.795	2.699	1.212	0.320	55446
71	0.502	0.0410	0.538	0.0174	0.749	2.475	1.208	0.350	22192
72	0.595	0.0444	0.728	0.0112	0.777	1.993	1.246	0.350	31087
73	0.555	0.0431	0.863	0.0075	1.129	2.341	1.230	0.350	86061

2.3 Correlation Between Various Roughness Measures

The correlation coefficients between various roughness measures are listed in Table 2. As would be expected from Table 1, almost all of the parameters are positively correlated with each other with the exception of Ω_4 . Thus it may be anticipated that, except for Ω_4 , a profile which is "rough" in one sense would probably be rough in another sense as well. The question is, then, which parameter can optimally characterize the wave propagation phenomenon. That is, which one of the roughness parameters is the best statistic to use in predicting the amplitude decay when some previously uncalibrated rugged paths are involved. The answer to such a question could well be dependent on the seismic phases of interest, since different seismic phase might interact with the rough topography differently. Throughout this study, R_g wave packet is injected into the model as the incident source, and the transmitted, reflected and the scattered synthetics are then analyzed. The ultimate output of this exercise would be some calibration curves which may be suitable for predicting the R_g amplitudes, given an arbitrary rugged profile. The same procedure should be repeated for other crustal phases to establish the associated relationship with the roughness measures, which will be addressed in the follow-up report.

Table 2. Correlation Coefficients Between Roughness Parameters							
	Ω_2	Ω_3	Ω_4	Ω_5	Ω_6	Ω_7	Pr[1]
Ω_1	0.99	0.58	-0.27	0.73	0.82	1.00	0.99
Ω_2	—	0.60	-0.27	0.73	0.87	0.99	0.99
Ω_3	—	—	-0.76	0.84	0.64	0.58	0.55
Ω_4	—	—	—	-0.58	-0.35	-0.27	-0.27
Ω_5	—	—	—	—	0.67	0.73	0.72
Ω_6	—	—	—	—	—	0.82	0.84
Ω_7	—	—	—	—	—	—	0.99

3. NUMERICAL EXPERIMENTS

3.1 Finite-difference Scheme

The 2-D linear finite-difference (LFD) scheme popularized by Kelly *et al.* (1976) is used with the Clayton and Engquist (1977) (Emmerman and Stephen, 1983) absorbing boundary conditions on both the sides and the bottom of the grid. Even with the absorbing boundary conditions, the simulations are run with large enough grids such that for the duration of the simulations reflections from the sides do not seriously contaminate the results. The free-surface boundary conditions follow from the work of Jih *et al.* (1988) and Jih (1993a) which allows for the introduction of arbitrary polygonal topography into the wave propagation simulations and which has been applied by McLaughlin and Jih (1988) for the modeling of teleseismic *P* waves from explosive line sources under realistic topographic surfaces. These boundary conditions are extensions to those of Ilan (1975 and 1977). Recently a number of techniques have been pursued in an effort to improve the computational performance of LFD solutions to wave equations. These include variable grids, higher order schemes, or implicit rather than explicit methods. Jih *et al.* (1988) have found that none of these methods provide significant improvement over the traditional explicit second order centered LFD schemes described by Alterman, Boore, and Kelly when rough topographic profiles are used at the free surface.

In the present experiments, the medium has *P*- and *S*-wave velocities of 5.02 and 2.898 km/sec respectively, corresponding to a Poisson's ratio of 0.35 and a Rayleigh wave velocity of 2.665 km/sec. The formulation generating the incident pure Rayleigh wave packet is analogous to Boore (1970) or Munasinghe and Farnell (1973) which has been used extensively by Martel *et al.* (1977), Fuyuki and Matsumoto (1980), Fuyuki and Nakano (1984), Levander (1985), and McLaughlin and Jih (1986 and 1987). The initial waveform is the fundamental mode Rayleigh wave in the homogeneous half space with a Ricker wavelet shape. This method is superior to another approach which shakes several mesh points on the free surface or the grid edge to generate the incident Rayleigh wave, since the latter would excite undesirable body waves as well. The pure Rayleigh wave packet of Ricker-wavelet shape is particularly suitable for the numerical modeling study, since it is well localized in both the time and wavenumber spaces. To reduce the grid dispersion, we have oversampled the incident wave packet by choosing the dominant wavelength to be 3.2 km = 32 ΔX , where $\Delta X = 0.1$ km is the grid spacing in the horizontal direction. The dominant wavenumber is 2.358 radians/km which corresponds to a wavelength of 2.665 km at 1 Hz. Thus the energy of our incident *R_g* wave packet is centered at 1 Hz.

The grids used in LFD simulations are 60 km in length and 50 km in depth, with a grid spacing of 0.1 km in both *X* and *Z* directions. The initial incident waveform, the reflected and the transmitted waveforms were then measured at free-surface "sensors". Transmission coefficients and the attenuation factor *Q*(*f*) were then computed in the frequency domain. The useful bandwidth is limited to frequencies below 2.4 Hz due to the limitation of 2nd order LFD scheme. Although we quote dimensions in km and velocities in km/s, it is possible to scale these simulations to higher or lower frequencies as desired. As explained earlier, the LFD scheme must discretize the topography into well-sampled polygons, which is exactly the reason for adopting a Markov sequence rather than a white sequence.

Therefore the smallest scale length of the topography is always twice the horizontal grid spacing. The largest scale length is limited by the total span of the rugged profile used in the simulation.

3.2 Half-space Experiment

Experiments were first conducted to justify that, in the case of a homogeneous half-space, the grid dispersion only slightly modulates the spectra of the propagating Rayleigh wave. A particularly informative way to visualize wave propagation through the models is by using numerical Schlieren diagrams. These "snapshots" of the wavefield traveling through the grid are generated by saving the displacement (or strain) at each grid point for a given time step. Figure 10 shows the snapshots of the displacement field at time incidents of 4 seconds apart. Shading in each snapshot is proportional to $\sqrt{U^2 + W^2}$ where U and W are the displacement along the X and Z directions, respectively, of the grid. The darkness of the plot is normalized to the maximum in each frame. No significant attenuation of the Rayleigh wave could be measured for the half-space in the frequency band of interest (Figure 11).

3.3 Experiments with Rough Topography

Following this check, we conducted 27 simulations with the random topographic profiles listed in Table 1. Each simulation took 4000 time steps. As in the half-space case, Figures 12 through 38 show snapshots of the displacement field due to a Rayleigh wave incident upon various topographic profiles. Successive frames are separated by intervals of 4 seconds, and the incident Rayleigh wave always travels from left to right. In general, the diffraction pattern becomes much more complicated when the topography is rougher. This is obvious in comparing Figure 13 (for model No.12) and Figure 32 (for model No.63), for instance. In all cases the corners act as point sources radiating converted body waves (mainly S wave).

Thirty sensors numbered from No.1 through No.30 are placed 2 km apart along the free surface to record the displacement. Figures 39 through 66 show the seismic section of the vertical component of each model with the maximum zero-to-peak amplitude shown on the right. The distance between each sensor and the "epicenter" of the initial Rayleigh wave packet is also shown. Smoother models tend to have longer reflected wave trains than do rougher models. Also, the peak amplitude of the transmitted signal, which is measured with trace No.29 of each model, drops significantly as the model becomes rougher. The reflected waves systematically consist of multiply reflected Rayleigh waves which last 22 seconds or longer, which is the time required for the R_g packet to cross the whole profile and then bounce back. On the other hand, the transmitted synthetic is dominated by very few cycles of Rayleigh waves. In the following, these qualitative observations are further elaborated in a quantitative manner.

The power spectra of traces No.2 and No.29 of each model are measured to represent the reflected and transmitted signal. We define the Rayleigh wave energy transmission coefficient, T, as $T(f) = \text{Power}_{\text{trans}}(f)/\text{Power}_{\text{inc}}(f)$ where $\text{Power}_{\text{inc}}(f)$ is the power spectrum of the incident Rayleigh wave. The reflection coefficient, R, is defined in an analogous way: $R(f) = \text{Power}_{\text{refl}}(f)/\text{Power}_{\text{inc}}(f)$. Table 2 gives the statistics of all 27 topographic profiles used and the corresponding attenuation factor Q at 1 Hz, which is the dominant frequency of the incident R_g packet. Here the quality factor, Q, is computed

via $\gamma = Q^{-1}(f) = -\ln(T(f)) \cdot (V_R/2\pi fX)$ as in McLaughlin and Jih (1986 and 1987).

Table 3. Transmission/Reflection/Scattering Statistics					
Model	T(1Hz)	R(1Hz)	1-T-R	Q(1Hz)	γ
11	0.360	0.181	0.459	65.6	0.0153
12	0.345	0.251	0.404	72.0	0.0139
13	0.371	0.207	0.422	81.1	0.0123
14	0.174	0.198	0.628	40.4	0.0248
15	0.320	0.207	0.473	58.2	0.0172
16	0.284	0.225	0.491	52.4	0.0191
21	0.138	0.237	0.625	33.9	0.0295
22	0.217	0.289	0.494	50.5	0.0198
23	0.148	0.188	0.664	37.1	0.0269
31	0.041	0.130	0.829	22.3	0.0449
32	0.076	0.249	0.675	28.2	0.0354
33	0.189	0.193	0.618	46.4	0.0215
41	0.063	0.181	0.756	26.0	0.0385
42	0.049	0.160	0.791	27.0	0.0371
43	0.165	0.143	0.692	44.0	0.0227
51	0.084	0.101	0.815	31.3	0.0320
52	0.047	0.229	0.724	22.8	0.0439
53	0.189	0.256	0.555	44.3	0.0226
61	0.209	0.073	0.718	64.9	0.0154
62	0.123	0.112	0.765	37.6	0.0266
63	0.053	0.064	0.883	23.7	0.0422
64	0.050	0.051	0.899	22.2	0.0450
65	0.133	0.079	0.788	35.1	0.0285
66	0.066	0.043	0.891	26.3	0.0380
71	0.091	0.068	0.841	32.3	0.0309
72	0.011	0.059	0.930	16.8	0.0596
73	0.006	0.047	0.947	15.2	0.0658

A significant conclusion is immediately apparent from Table 3, that the reflected energy and transmitted energy is far from 100% of the incident energy, and that body wave conversion must be very efficient. Even the smoothest model (such as model No.12) caused a scattering loss of at least 40%. In the extreme case of model No.73, nearly 95% of the Rayleigh wave energy is lost to body wave conversion, which results in a very low quality factor. The model which yields the highest value of Q has a

transmission coefficient of about 37%, and about 42% of R_p energy is lost to scattering. The spatial Q values associated with rough topography as listed in Table 3 are in the same range as the Q_p of the uppermost crust in many places including the Arabian shield (Mokhtar, *et al.*, 1988), the eastern folded region of the Arabian Peninsula (Seber and Mitchell, 1991), Maine (Al-Eqabi and Herrmann, 1993), and different portions of New England (Saikia *et al.*, 1990; Saikia, 1992).

The nature of the reflected and transmitted signals can be determined with the polarity. Figures 68 through 94 show the synthetics at surface sensors No.2 and No.29, which have been used to represent the reflected and transmitted waves, respectively, in Table 3. Vertical and horizontal components are plotted in solid and dashed lines, respectively. The particle motion shown on the left clearly exhibits the retrograde motion. For comparison, the synthetics recorded at a deep sensor are shown at the bottom of each figure. This sensor, being 37.5 km in depth, records only the scattered body waves, as is indicated by the nearly linear particle motions.

The four propagation parameters, namely γ , T, R, and 1-T-R, have been regressed against each individual roughness coefficients separately, as shown in Figures 95 through 103. Table 4 summarizes the correlation between various roughness measures and the R_p propagation characteristics. Ω_1 and Ω_2 have the highest correlation (0.87 and 0.88, respectively) with the scattering loss. This is also illustrated in lower-right plot of Figures 95 through 103. Note that Ω_1 and Ω_2 perform better in predicting the scattering loss than in predicting the transmission or reflection alone. For a practical monitoring situation, however, it might be desirable to infer the transmission coefficient, T, of an uncalibrated path in order to gain some information about how the seismic wave behaves. On this regard, Ω_1 , Ω_2 , and Ω_6 might serve the purpose equally well, with the correlation coefficients around 0.73-0.76. Ω_4 , the Durbin-Watson number or the von Neumann ratio, turns out to be the poorest statistics in all tests. The correlation coefficient between Ω_4 and any of the propagation statistics is always no higher than 0.27 (Figure 98). As discussed earlier, Ω_4 is essentially the square of the quotient of two other roughness measures, namely Ω_2 and Ω_3 . Thus combining these two parameters offers no advantage at all. That Ω_4 is negatively correlated to all other roughness measures (*cf.* Table 2), scatter loss, as well as γ , would suggest that Ω_4 is not a good candidate for quantifying the roughness. Several systematic patterns can be observed from the regression results: both γ and the scattering loss (1-T-R) increase with the roughness coefficients (except Ω_4), whereas T and R decrease with the roughness coefficients.

Table 4. Correlation Between Roughness and Propagation Characteristics

	T(1Hz)	R(1Hz)	1-T-R	Ω_1	Ω_2	Ω_3	Ω_4	Ω_5	Ω_6	Ω_7	Pr[1]
γ	-0.88	-0.54	0.84	0.67	0.66	0.42	-0.17	0.31	0.49	0.66	0.64
T(1Hz)	—	0.54	-0.92	-0.73	-0.76	-0.54	0.24	-0.43	-0.74	-0.73	-0.73
R(1Hz)	—	—	-0.83	-0.81	-0.79	-0.49	0.24	-0.65	-0.57	-0.81	-0.80
1-T-R	—	—	—	0.87	0.88	0.59	-0.27	0.59	0.76	0.86	0.86

Table 5. Regression Results					
X	Y	Slope	Intercept	$\sigma(Y)$	ρ
Ω_1	γ	0.057 ± 0.013	0.013 ± 0.004	0.010	0.67
Ω_1	T(1Hz)	-0.501 ± 0.095	0.306 ± 0.033	0.077	-.73
Ω_1	R(1Hz)	-0.393 ± 0.056	0.280 ± 0.020	0.045	-.81
Ω_1	1-T-R	0.894 ± 0.104	0.413 ± 0.036	0.084	0.87
Ω_2	γ	1.069 ± 0.242	-0.003 ± 0.008	0.010	0.66
Ω_2	T(1Hz)	-9.915 ± 1.686	0.462 ± 0.055	0.072	-.76
Ω_2	R(1Hz)	-7.206 ± 1.117	0.384 ± 0.037	0.048	-.79
Ω_2	1-T-R	17.121 ± 1.869	0.154 ± 0.061	0.080	0.88
Ω_3	γ	0.019 ± 0.008	0.019 ± 0.006	0.013	0.42
Ω_3	T(1Hz)	-0.199 ± 0.062	0.268 ± 0.041	0.094	-.54
Ω_3	R(1Hz)	-0.127 ± 0.045	0.233 ± 0.030	0.068	-.49
Ω_3	1-T-R	0.326 ± 0.089	0.499 ± 0.060	0.135	0.59
Ω_4	γ	-0.234 ± 0.274	0.034 ± 0.004	0.014	-.17
Ω_4	T(1Hz)	2.667 ± 2.181	0.114 ± 0.035	0.108	0.24
Ω_4	R(1Hz)	1.878 ± 1.527	0.132 ± 0.024	0.076	0.24
Ω_4	1-T-R	-4.546 ± 3.239	0.754 ± 0.052	0.161	-.27
Ω_5	γ	0.011 ± 0.007	0.023 ± 0.005	0.013	0.31
Ω_5	T(1Hz)	-0.127 ± 0.054	0.234 ± 0.041	0.101	-.43
Ω_5	R(1Hz)	-0.136 ± 0.032	0.248 ± 0.024	0.059	-.65
Ω_5	1-T-R	0.263 ± 0.072	0.518 ± 0.055	0.135	0.59
Ω_6	γ	0.011 ± 0.004	0.009 ± 0.008	0.012	0.49
Ω_6	T(1Hz)	-0.131 ± 0.024	0.418 ± 0.051	0.075	-.74
Ω_6	R(1Hz)	-0.070 ± 0.020	0.301 ± 0.044	0.064	-.57
Ω_6	1-T-R	0.202 ± 0.035	0.281 ± 0.074	0.109	0.76
Ω_7	γ	0.137 ± 0.031	-0.124 ± 0.035	0.010	0.66
Ω_7	T(1Hz)	-1.210 ± 0.229	1.517 ± 0.259	0.077	-.73
Ω_7	R(1Hz)	-0.949 ± 0.136	1.229 ± 0.154	0.046	-.81
Ω_7	1-T-R	2.159 ± 0.251	-1.746 ± 0.284	0.084	0.86
Pr[1]	γ	0.080 ± 0.019	0.015 ± 0.004	0.011	0.64
Pr[1]	T(1Hz)	-0.734 ± 0.139	0.294 ± 0.031	0.077	-.73
Pr[1]	R(1Hz)	-0.566 ± 0.085	0.269 ± 0.019	0.047	-.80
Pr[1]	1-T-R	1.300 ± 0.156	0.437 ± 0.035	0.086	0.86

3.5 Scattered Body Waves

A horizontal array is formed of 30 sensors spaced 2 km apart at a depth of 37.5 km to record the converted *P* and *SV* wavefields. Figures 103 through 129 give the seismic sections of the converted *P* wave (top) and *S* wave (bottom) displacements for each model. The take-off angle as well as the zero-to-peak amplitude of each synthetic are shown on the right. The seismic sections are plotted in a uniform scale. Note that the converted *SV* waves typically have a peak amplitude two to three times larger than that of the converted *P* waves. The *P* and *S* wavefields can be seen to be radiated from numerous point diffractors along the topographic profile, as was already suggested by the snapshots (Figures 12-38). For the lower portion of the seismic section, *i.e.*, synthetics numbered 50 and on, the take-off angles are generally more oblique than 30°. If a velocity gradient were introduced into the model, most of these rays would pass the critical angle and could well be multiply reflected in the crustal waveguide.

In plotting the seismic sections, each synthetic seismogram is steered towards its ray direction which is determined with the particle motion within an appropriate time window. To illustrate the robustness of this approach in separating *P* and *SV* components, Figures 130 through 156 display three synthetic seismograms for each model. The particle motion throughout the whole LFD simulation (*i.e.*, 40-second window) is shown on the left, with the *P* and *SV* components shown in solid and dashed lines, respectively, on the right. Traces 31, 40, and 59 of each model are plotted from top to bottom. The take-off angle of each ray is determined by the *P* onset, and it turns out that within the initial *P* window (typically from 10 to 15 seconds), the *SV* component is nearly negligible. On the other hand, the later arrivals (*e.g.*, 20 seconds and on) are dominated by *SV* component with peak amplitude a few times larger than that of the *P* waves, except for the obliquely scattered trace (*e.g.*, the synthetic No.59) of a few models.

Although the topography is embedded in the central portion of the grid, the scattered *S* wave field is far from isotropic. The backscattered *S* waves have steeper take-off angles and longer duration, whereas the forward scattered *S* waves have more compact wavetrains. There are twice as many sensors that recorded forward-scattered *S* waves. Furthermore, many of them have very oblique take-off angles. This is in support of the interpretation that we are observing a series of *S*-wave point sources spread along the free surface which are "triggered" in the forward direction. Thus even if we assume that the subsurface geology is perfectly homogeneous and isotropic, the scattered *S* wavefield will not be as symmetric. Both the forward and backward directions have about the same number of rays that would penetrate into the deeper earth. However, there is always a significant amount of energy which is favorably trapped in the crustal waveguide in the forward direction.

4. DISCUSSION AND CONCLUSIONS

In this study, we have performed 2-D numerical Rayleigh-wave scattering experiments upon complicated random topographies. The simulations show that reflection is an efficient process and that the bulk of the energy which is not transmitted across the topography is either converted to body waves or reflected back. Through the simulations, we illustrate that P and S waves are radiated as coda to teleseismic distances, and some P -SV energy is trapped in the crustal waveguide as P_g , S_g , and L_g . The body waves appear to radiate from the changes in slope and to first order can be visualized as being from point-force diffractors. All these observations are consistent with our previous study (McLaughlin and Jih, 1986 and 1987; Jih and McLaughlin, 1988).

The spatial Q values associated with rough topography obtained in this study are in the same range as the Q_p of the uppermost crust in many places including the Arabian shield (Mokhtar, *et al.*, 1988), the eastern folded region of Arabian Peninsula (Seber and Mitchell, 1991), and Maine (Al-Eqabi and Hermann, 1993). Saikia (1992) (and Saikia *et al.*, 1990) also finds that a low Q_p of 15 is needed in order to match his R_g synthetics with the data observed at southwestern New England. An accurate characterization/prediction of the propagation of regional phases due to explosion sources in regions of high proliferation concern requires an accurate regionalized map of the attenuation coefficient. Although a global L_g coda Q map is available for much of Eurasia and some other regions of the world, the identification of small seismic events has raised a need to refine such a map for a more detailed regionalization for complex areas. It is known that changes in the quality factor of the propagation path can have a significant influence on magnitude estimates and therefore on network performance estimates (*e.g.*, Jih and Lynnes, 1993). Regionalized Q maps (for different phases) need to be established and must be coupled with the appropriate source model for the distinct geologies.

A major issue for the Non-Proliferation Treaty is the discrimination of large chemical explosions from possible clandestine or small nuclear tests. Unless discrimination is possible, the numerous mining blasts could give ample opportunity for concealing clandestine tests. Rippled-fired explosions are commonly used to fragment rocks during quarry and open-pit mining. Through LFD calculations, Jih (1993b) finds that ripple firing could excite directionally dependent R_g and S^* . Thus the lack of R_g may not be always indicative of a deep source. Rather, it could also be due to the shot pattern. However, the enhanced R_g in the forward direction of ripple firing can be strongly attenuated by lateral heterogeneity and surface topography, as is illustrated in the present study. The scattered R_g energy could then couple into the crustal waveguide as L_g and other phases. Since such scattering mechanisms are commonly present in many quarry sites or mines, it is not surprising that the directional enhancement of R_g may not be always observable. The spall could obscure the azimuthal dependency of R_g as well. LFD modeling studies suggest that the R_g -to- S scattering is in general stronger than that of R_g -to- P , which could provide a plausible explanation of why quarry blasts and mining blasts should discriminate less well from earthquakes than would contained nuclear explosions.

The L_g phase has an increasingly prominent role in nuclear test detection, discrimination, and yield estimation. Regional L_g phase is a short-period guided wave, composed mainly of a sequence of

multiply reflected postcritical S -waves trapped in the crustal waveguide. The formation of L_g requires a significant amount of energy propagating as S waves, either directly radiated from the source or converted from other phases, and these S waves must be properly trapped in the crustal wave guide (Xie and Lay, 1993; Frankel, 1989; and others). Shallow explosions are strong R_g generators, and these explosion-generated R_g waves can contribute to L_g via scattering at rough topography. LFD simulations using a pure R_g packet as the initial condition offers a promising approach to quantify effects of scattering by topography and heterogeneity upon surface waves, as illustrated in this study. A complete exploration of the problem will require variation of the P and S velocities, near surface velocity gradients, as well as crustal velocity heterogeneity, since the low- Q sediments can be equally attenuative, as reported by Mitchell and Hwang (1987). Adding any of these mechanisms to the numerical experiments can only increase the S coupling (*cf.* Aki, 1992). Thus we can anticipate that in a more realistic geological environment, the Rayleigh-to- L_g conversion would be more profound than in the case of a half space. Recently Patton and Taylor (1993) observed L_g spectral null around 0.55 Hz for Yucca Flat explosions, which could be due to the null in excitation of R_g by a CLVD source as a function of depth. The null can not be accounted for by the delay between P and spall slapdown when those differ for shots at constant depth but different yield. Thus the scattering of large amplitude R_g waves in the near field may be the most important source of L_g waves with frequencies near 1 Hz for explosions on Yucca Flat or mountainous site.

Zhang and Lay (1993) found the S_n/L_g amplitude ratio to be strongly dependent on some roughness measures of paths from Semipalatinsk to several Eurasian stations. Perhaps S_n interacts with the irregular Moho topography in a way very similar to that of R_g with the free-surface topography. Thus this may suggest that energy partitioning in the regional wavefield is controlled by waveguide structure and attenuation variations which are manifested in the surface topography. Further investigation along this line with numerical modeling techniques as presented in this study would be very useful. A distinct advantage of using a source-free Rayleigh wave packet in the simulation (as adopted in this study) is that the interaction with certain types of heterogeneity (such as the topography) can be isolated. Scaling our results with other source-dependent relationships (such as the depth-dependence of R_g excitation) is straightforward.

The simple functional relationship between some of the roughness parameters might lead us to regard some of the roughness parameters as redundant. However, it turns out that the performance of these roughness measures could be different. This simply means that by applying appropriate "transformation" on the data, we might be able to find a better linear regression. A useful family of transformations for this purpose is the family of *Box-Cox transformations* (see, for example, Johnson and Wichern, 1992). When we regress γ and the transmission power ($T(1\text{Hz})$) on any of the roughness measures, say Ω_1 , it should not be surprising to see that a linear fit is appropriate for γ , but not $T(1\text{Hz})$. Converting $T(1\text{Hz})$ to γ with a simple logarithmic operation is a typical example of the Box-Cox transformation. Such an exercise of transforming nonnormal data into more nearly "normal looking" data (around the calibration curve) is a standard practice in the statistics field, and it may be worth exploring.

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7. FIGURE CAPTIONS

Figure 1: 3 rugged profiles corresponding to models No.11 through No.13, respectively, are shown on the left, with the log-amplitude wavenumber spectra of the topography in the center, and statistics characterizing the topography listed on the right. The log-amplitude wavenumber spectra are normalized by the peak value of the spectra (which is shown at the right as $K(0)$). The seed number and the preassigned probability of state 1, which determine the random topography, are printed under the profile.

Figures 2-9: Same as Figure 1 except for models No.14 through No.73.

Figure 10 The snapshots of the displacement field at time incidents of 4 seconds apart. Shading in each snapshot is proportional to $\sqrt{U^2 + W^2}$ where U and W are the displacement along the X and Z directions, respectively, of the grid. The darkness of the plot is normalized to the maximum in each frame.

Figure 11: Spectral ratio of the transmitted Rayleigh waves over the incident Rayleigh waves in a homogeneous half-space. Grid dispersion only modulates the spectra slightly. The frequency band of interest in this study is around 1 Hz. No significant attenuation of the Rayleigh wave could be measured for the half-space in the frequency band of interest.

Figure 12: The snapshots of the displacement field due to a Rayleigh wave incident upon topographic profile No.11.

Figures 13-38: Same as Figures 10 and 12 except for models No.12 through No.73. In general, the diffraction pattern becomes much more complicated when the the topography is rougher. This is obvious in comparing Figure 13 (for model No.12) and Figure 32 (for model No.63), for instance. In all cases the corners act as point sources radiating converted body waves (mainly S wave).

Figure 39: The seismic section of the vertical component of the half-space model. The sensors are evenly distributed (2 km apart) along the free-surface. The maximum zero-to-peak amplitude of each trace is shown on the right.

Figures 40-66: Same as Figure 39 except for models No.12 through No.73. Smoother models tend to have longer reflected wave trains than do rougher models. Also, the peak amplitude of the transmitted signal, which is measured with trace No.29 of each model, drops significantly as the model becomes rougher. In the following, these qualitative observations are further elaborated in a quantitative manner.

Figure 67: The synthetics for the half-space model at three different distances are shown on the right with the vertical and horizontal components are plotted in solid and dashed lines, respectively. The particle motion is plotted at the left. Note the clear retrograde motion.

Figure 68: The synthetics at surface sensors No.2 and No.29, which have been used to represent the reflected and transmitted waves, respectively, in Table 3. Same as in Figure 67, the vertical and horizontal components are plotted in solid and dashed lines, respectively. The reflected waves (top) is composed of multiply reflected Rayleigh waves. On the other hand, the transmitted synthetic (middle) is dominated by very few cycles of Rayleigh waves. The particle motion shown on the left clearly exhibits the retrograde motion. For comparison, the synthetics recorded at a deep sensor are shown at the bottom of each figure. This sensor, being 37.5 km in depth, records only the scattered body waves, as is indicated by the nearly linear particle

motions.

Figures 69-94: Same as Figure 68 except for models No.12 through No.73.

Figure 95: The four propagation parameters (γ , T , R , and $1-T-R$) are regressed against Ω_1 . The correlation of 0.87 between Ω_1 and the scattering loss is statistically significant.

Figures 96-102: Same as Figure 95 except for different roughness measures. Ω_1 and Ω_2 perform better in predicting the scattering loss than in predicting the transmission or reflection alone. Ω_4 , the Durbin-Watson number or the von Neumann ratio, turns out to be the poorest statistics in all tests. The correlation coefficient between Ω_4 and any of the propagation statistics is always no higher than 0.27 (Figure 98). Several systematic patterns can be observed from the regression results: both γ and the scattering loss ($1-T-R$) increase with the roughness coefficients (except Ω_4), whereas T and R decrease with the roughness coefficients.

Figure 103: The seismic sections of the converted P wave (top) and S wave (bottom) displacements of model No.11. The take-off angle and the zero-to-peak amplitude of each synthetic are shown on the right.

Figures 104-129: Same as Figure 103 except for models No.12 through No.73. Note that the converted SV waves typically have a peak amplitude two to three times larger than that of the converted P waves. For the lower portion of the seismic section, *i.e.*, synthetics numbered 50 and on, the take-off angles are generally more oblique than 30° .

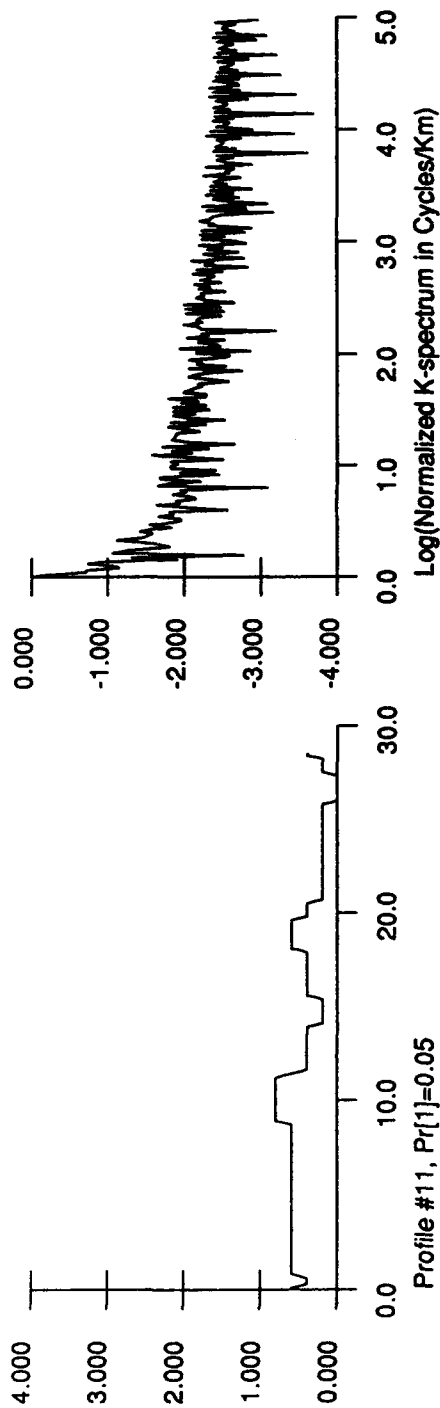
Figure 130: Three (rotated) synthetic seismograms, (traces No.31 (top), No.40 (middle), and No.59 (bottom)), generated with model No.11. The P and SV components are shown in solid and dashed lines, respectively. The particle motion throughout the whole 40-second window is shown on the left. The take-off angle of each ray is determined by the P onset.

Figures 131-156: Same as Figure 130 except for models No.12 through No.73. Note that within the initial P window (typically from 10 to 15 seconds), the SV component is nearly negligible. Later arrivals (*e.g.*, 20 seconds and on) are dominated by SV component with the peak amplitude a few times larger than that of the P waves, except for the obliquely scattered trace (*e.g.*, the synthetic No.59) of a few models.

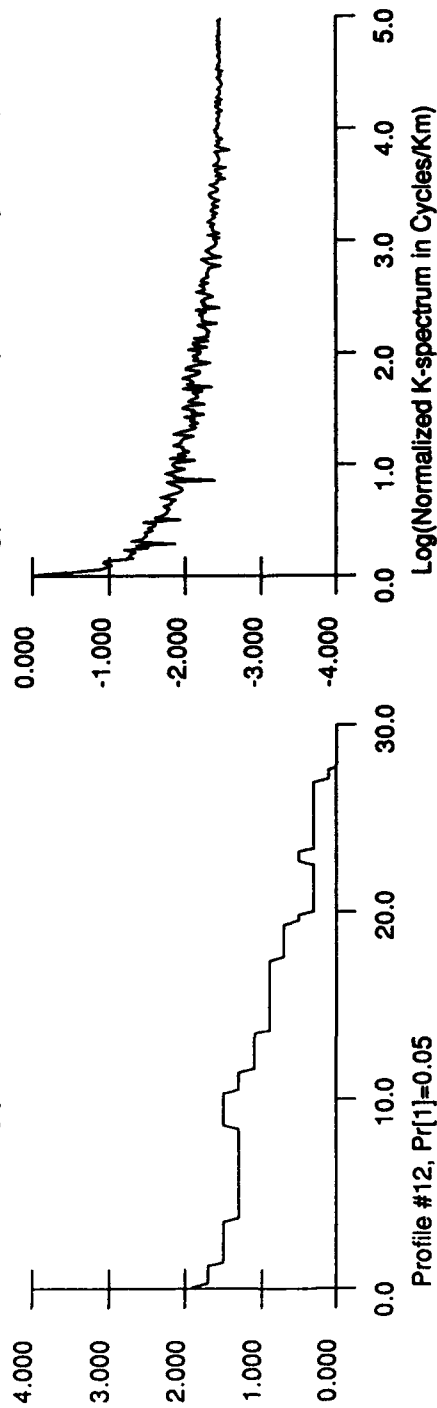
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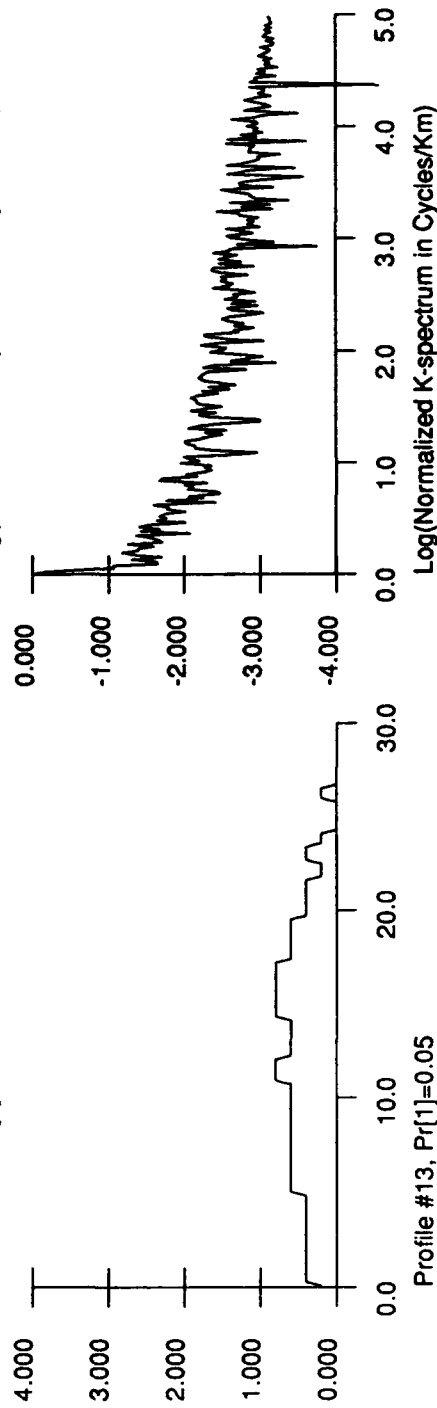
..



$Pr[1] = 0.05$, Seed = 22887
[L1-jumps]/km = 0.0809
[L2-jumps]/km = 0.0178
RMS elevation = 0.2145
Durbin-Watson # = 0.0196
Peak K-Spectrum = $K(0) = 0.2404$
0.84 Corners/km
(24 corners / 28.60km)
Normalized arc length= 1.038

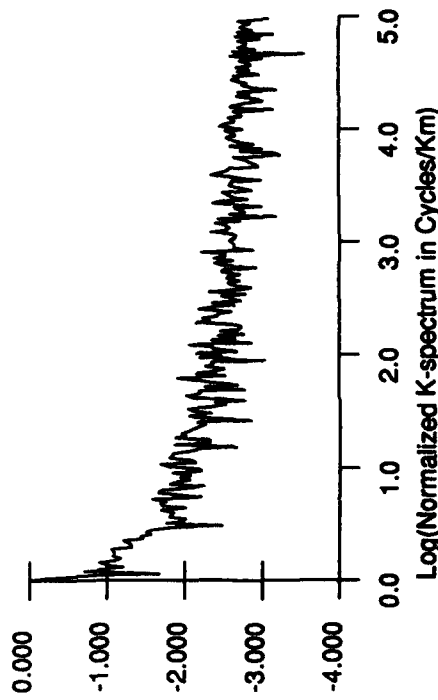
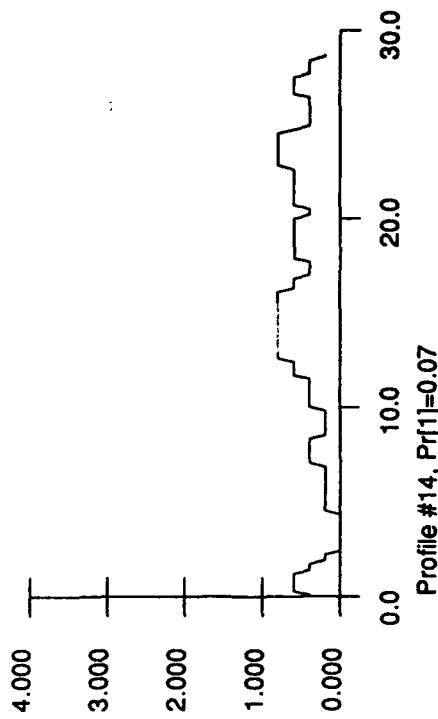


$Pr[1] = 0.05$, Seed = 22882
[L1-jumps]/km = 0.0868
[L2-jumps]/km = 0.0186
RMS elevation = 0.4866
Durbin-Watson # = 0.0041
Peak K-Spectrum = $K(0) = 0.5113$
1.00 Corners/km
(28 corners / 27.90km)
Normalized arc length= 1.040

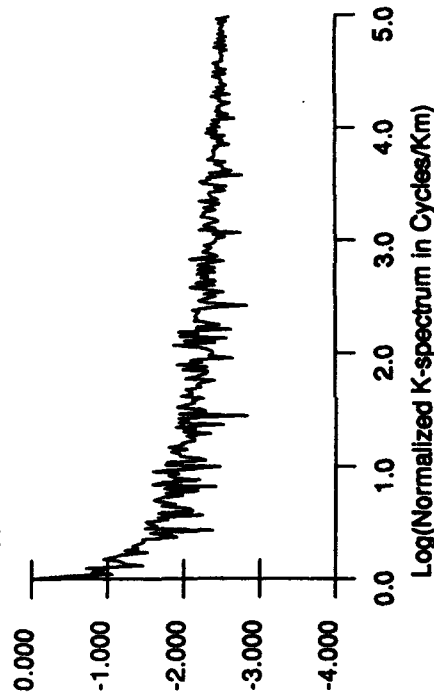
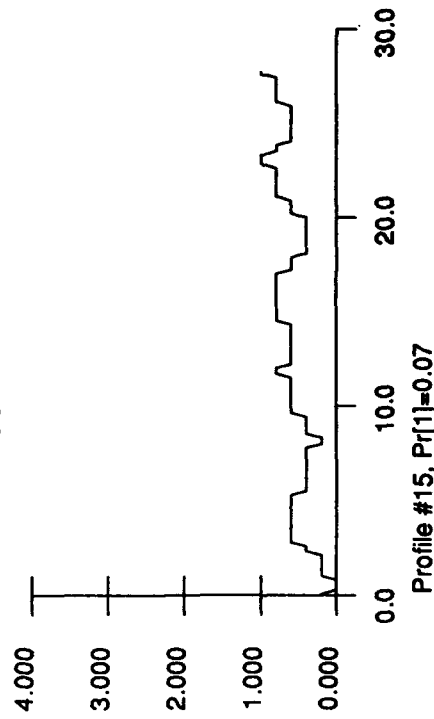


$Pr[1] = 0.05$, Seed = 85995
[L1-jumps]/km = 0.0967
[L2-jumps]/km = 0.0190
RMS elevation = 0.2181
Durbin-Watson # = 0.0203
Peak K-Spectrum = $K(0) = 0.2596$
0.97 Corners/km
(26 corners / 26.90km)
Normalized arc length= 1.040

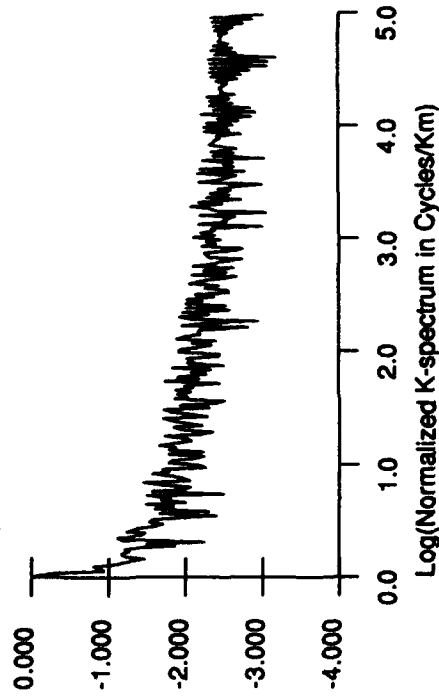
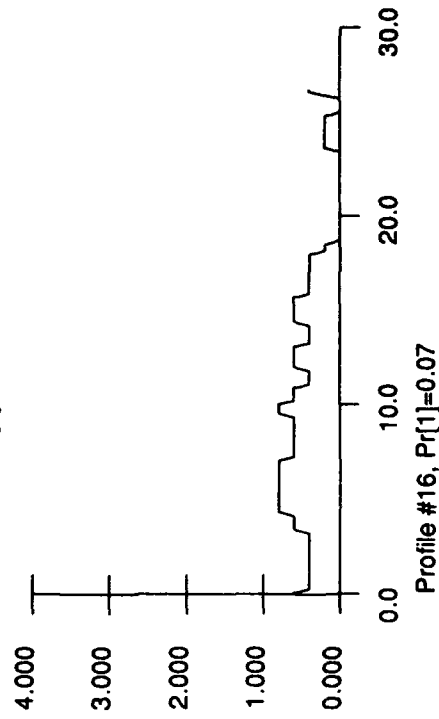
Figure 1



Pr[1] = 0.07, Seed = 91333
 [L1-jumps]/km = 0.1459
 [L2-jumps]/km = 0.0225
 RMS elevation = 0.2342
 Durbin-Watson # = 0.0266
 Peak K-Spectrum = K(0) = 0.2662
 1.39 Corners/km
 (40 corners / 28.80km)
 Normalized arc length= 1.060



Pr[1] = 0.07, Seed = 91350
 [L1-jumps]/km = 0.1439
 [L2-jumps]/km = 0.0228
 RMS elevation = 0.2093
 Durbin-Watson # = 0.0329
 Peak K-Spectrum = K(0) = 0.3096
 1.44 Corners/km
 (40 corners / 27.80km)
 Normalized arc length= 1.060



Pr[1] = 0.07, Seed = 91285
 [L1-jumps]/km = 0.1269
 [L2-jumps]/km = 0.0218
 RMS elevation = 0.2646
 Durbin-Watson # = 0.0181
 Peak K-Spectrum = K(0) = 0.2092
 1.19 Corners/km
 (32 corners / 26.80km)
 Normalized arc length= 1.053

Figure 2

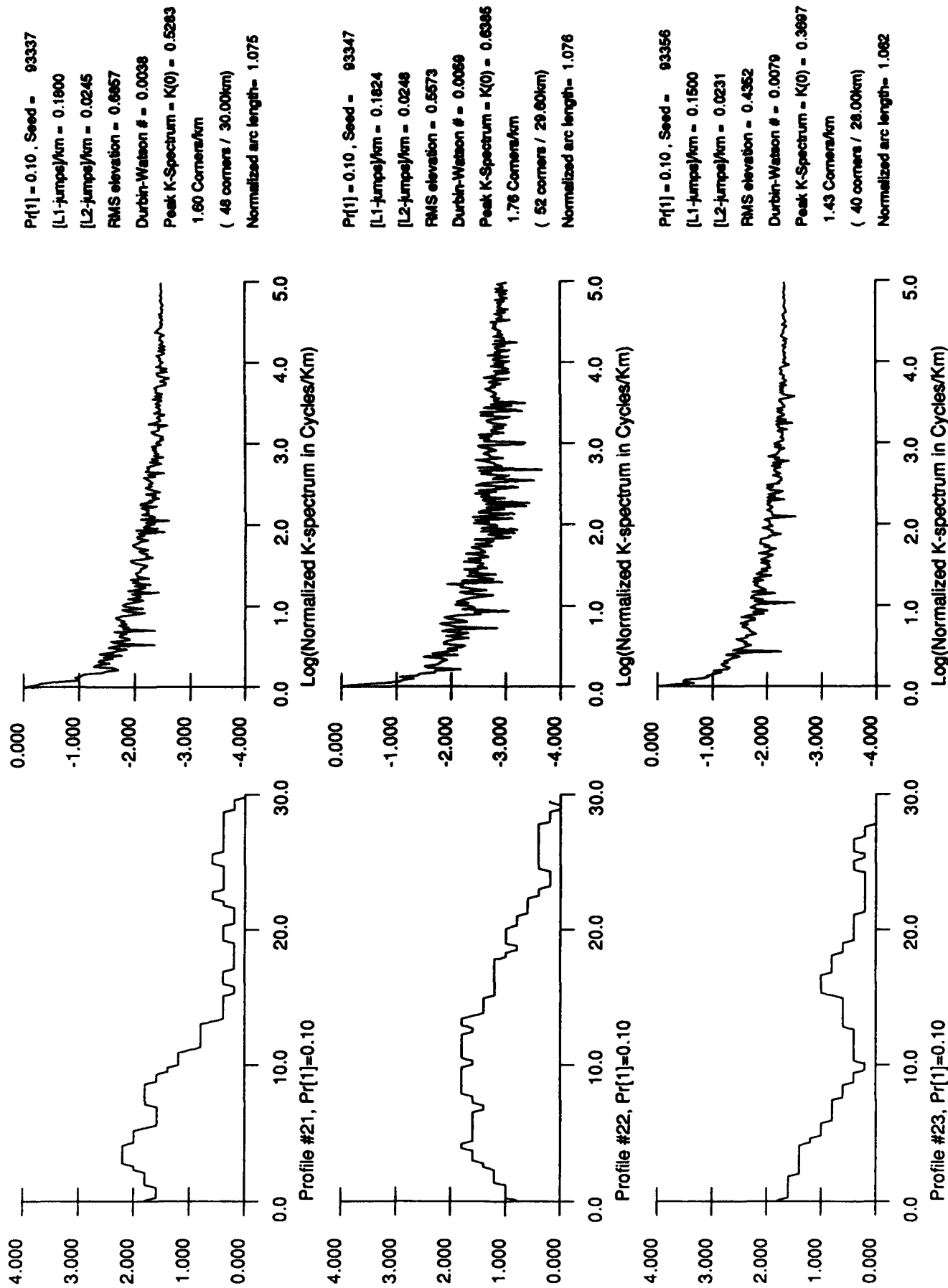
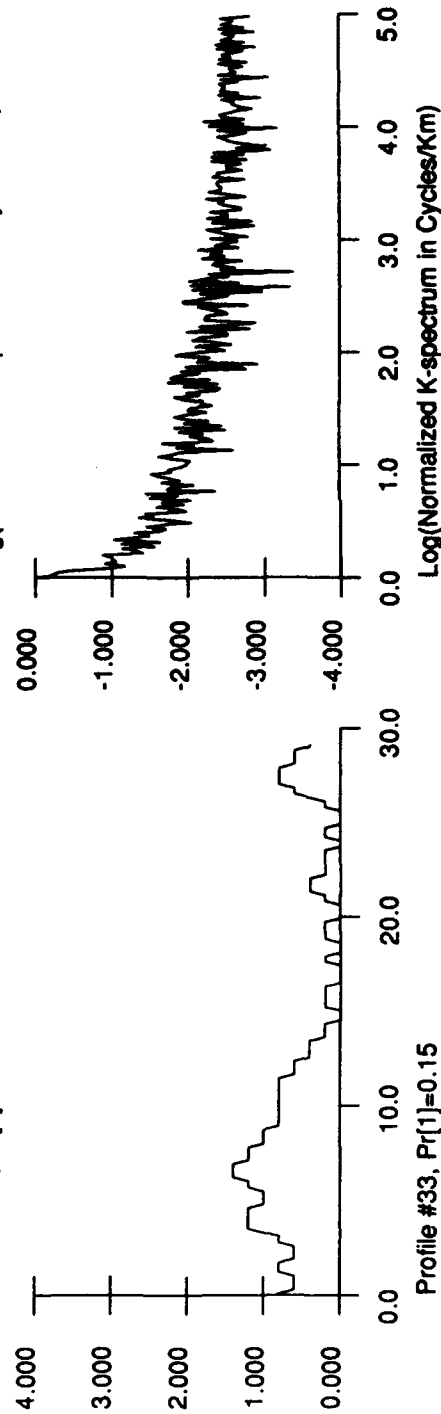
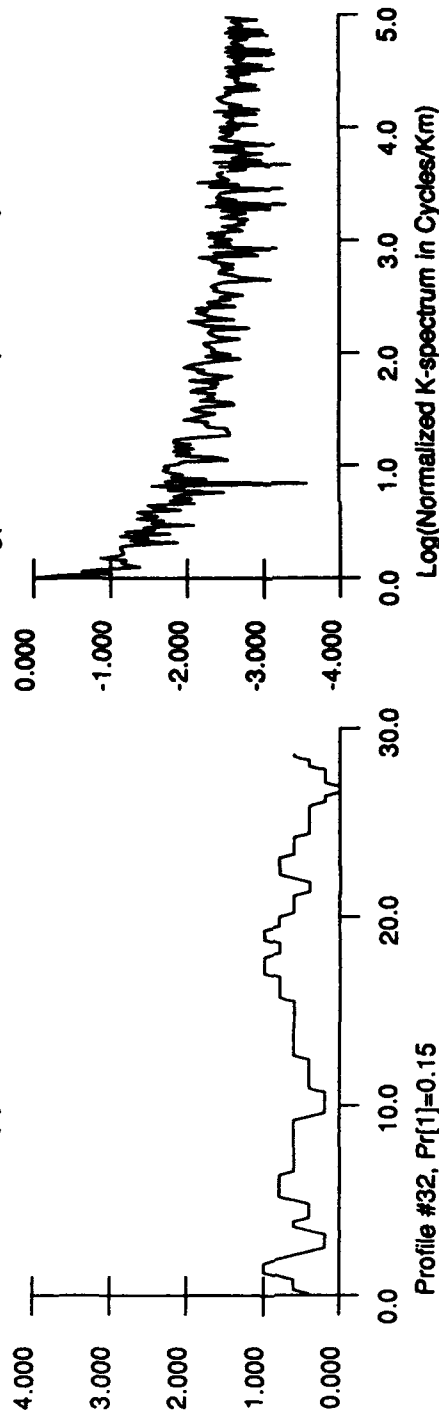
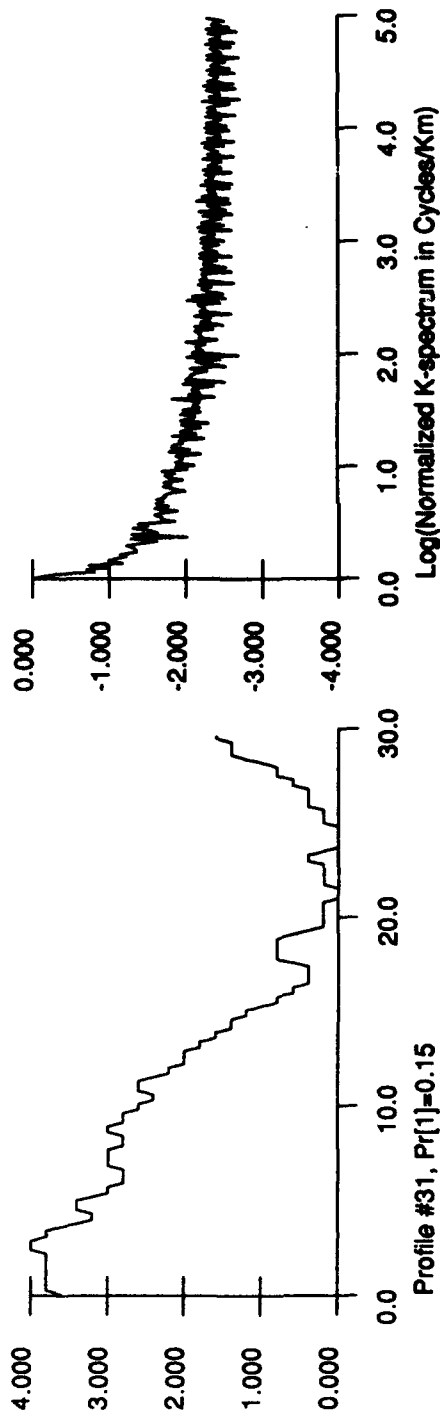


Figure 3



$Pr[1] = 0.15$, Seed = 749546615
 [L1-jumps]/km = 0.3098
 [L2-jumps]/km = 0.0323
 RMS elevation = 1.3283
 Durbin-Watson # = 0.0018
 Peak K-Spectrum = $K(0) = 0.9612$
 2.36 Corners/km
 (70 corners / 28.70km)
 Normalized arc length= 1.128

$Pr[1] = 0.15$, Seed = 20333
 [L1-jumps]/km = 0.2300
 [L2-jumps]/km = 0.0283
 RMS elevation = 0.2338
 Durbin-Watson # = 0.0421
 Peak K-Spectrum = $K(0) = 0.3174$
 1.74 Corners/km
 (50 corners / 28.70km)
 Normalized arc length= 1.095

$Pr[1] = 0.15$, Seed = 98016
 [L1-jumps]/km = 0.2329
 [L2-jumps]/km = 0.0282
 RMS elevation = 0.4078
 Durbin-Watson # = 0.0140
 Peak K-Spectrum = $K(0) = 0.3027$
 2.19 Corners/km
 (64 corners / 29.20km)
 Normalized arc length= 1.098

Figure 4

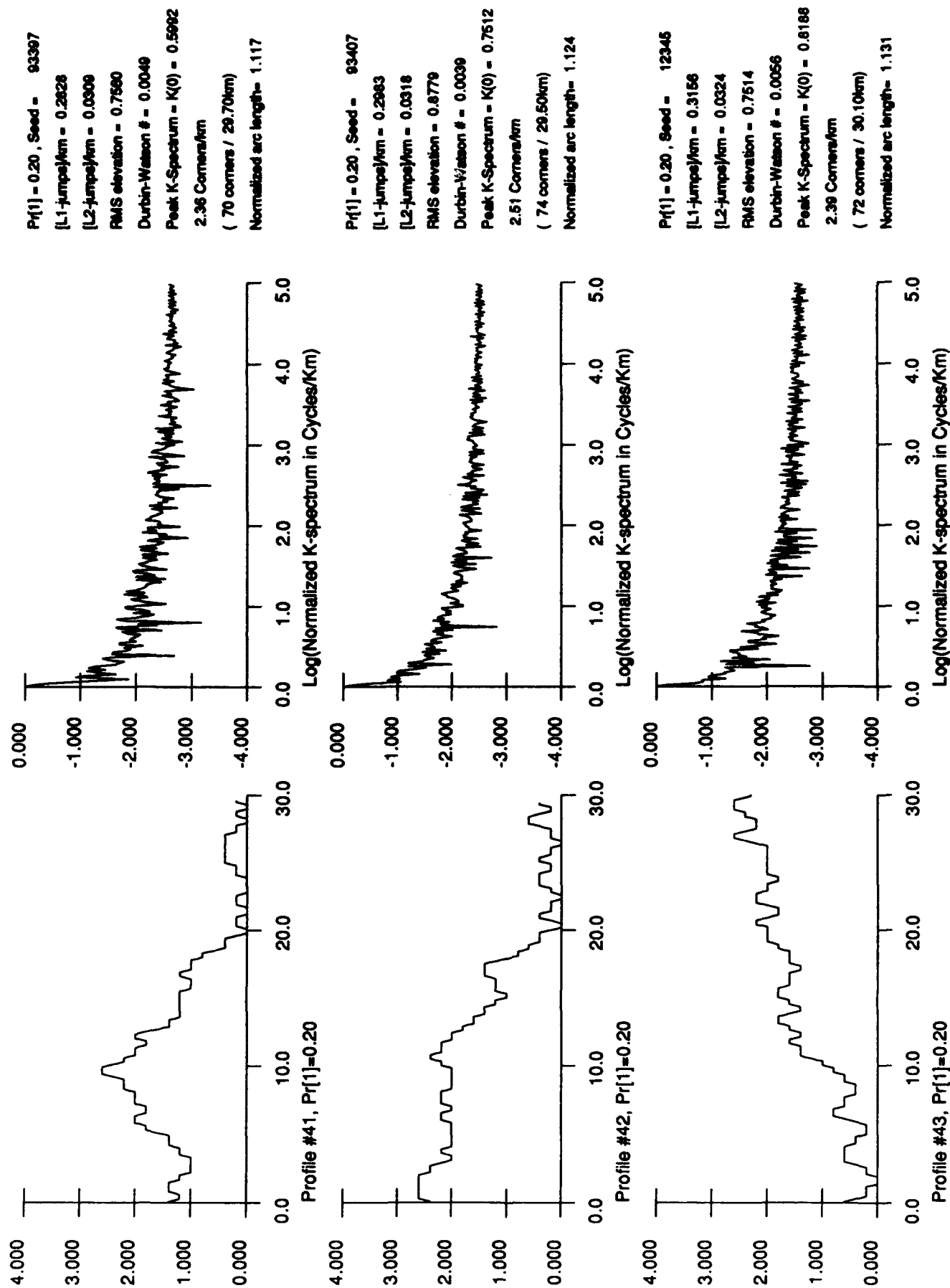


Figure 5

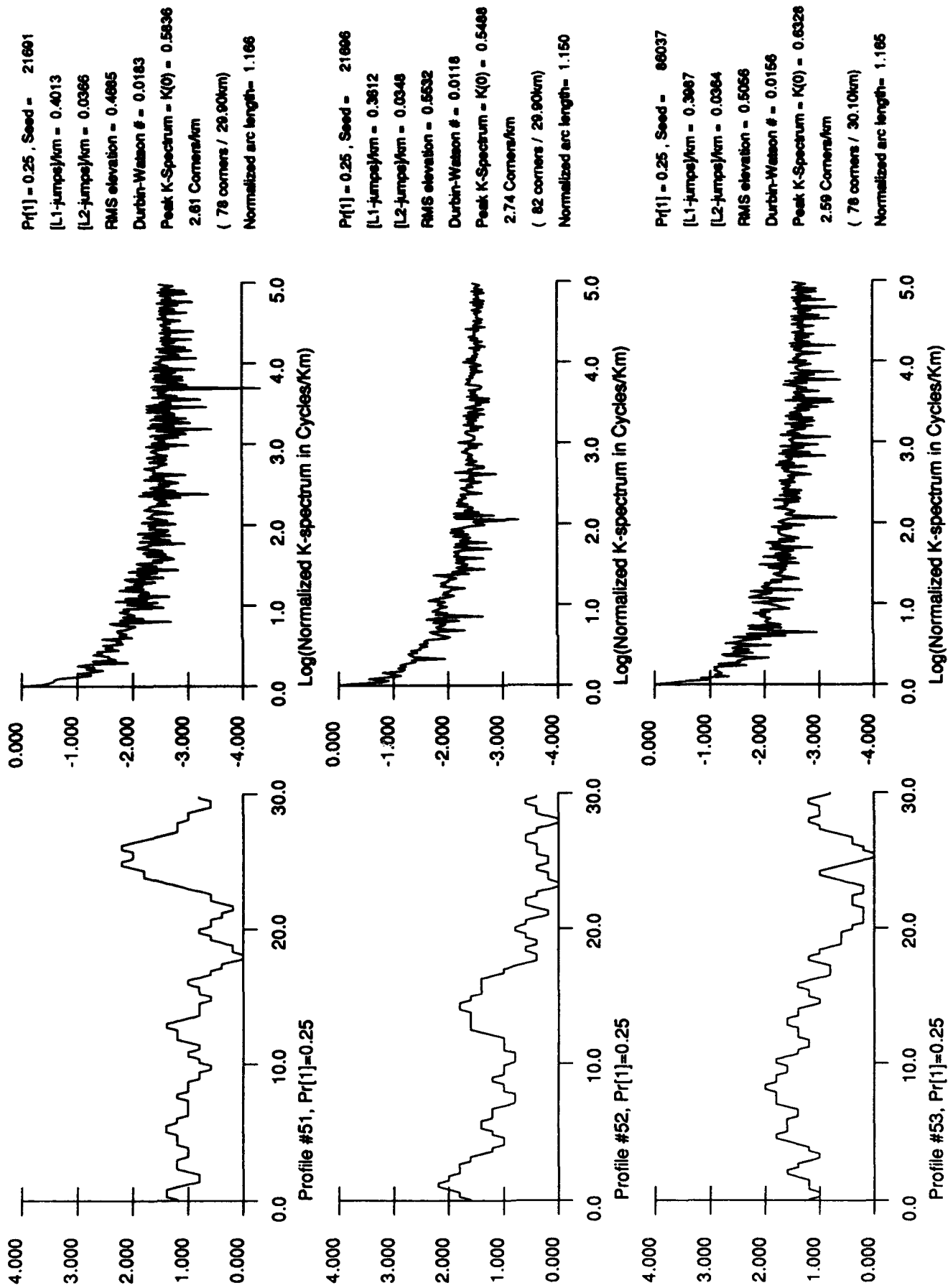
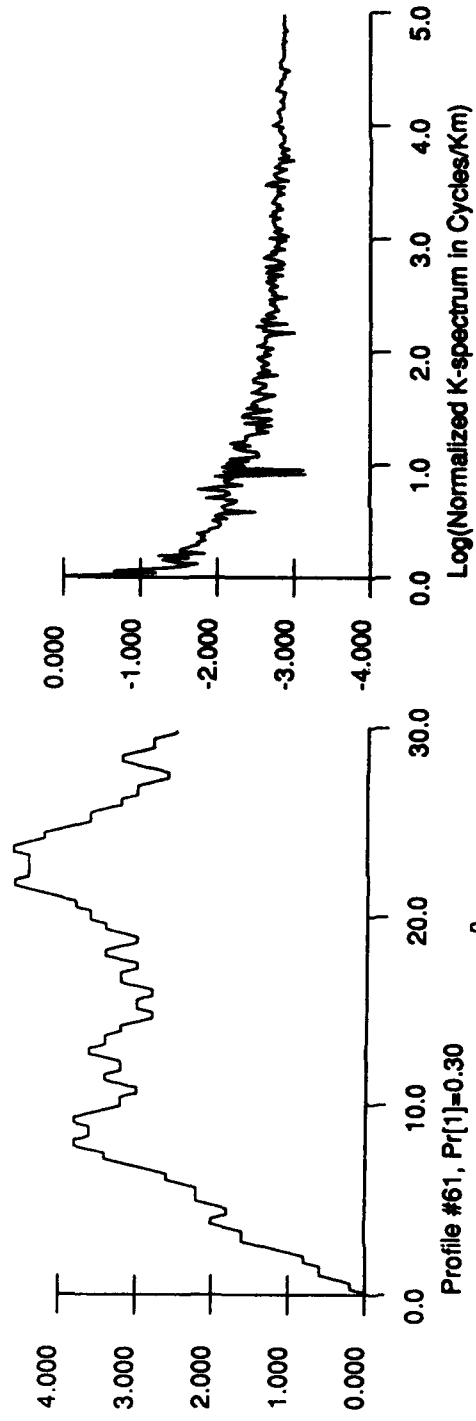


Figure 6

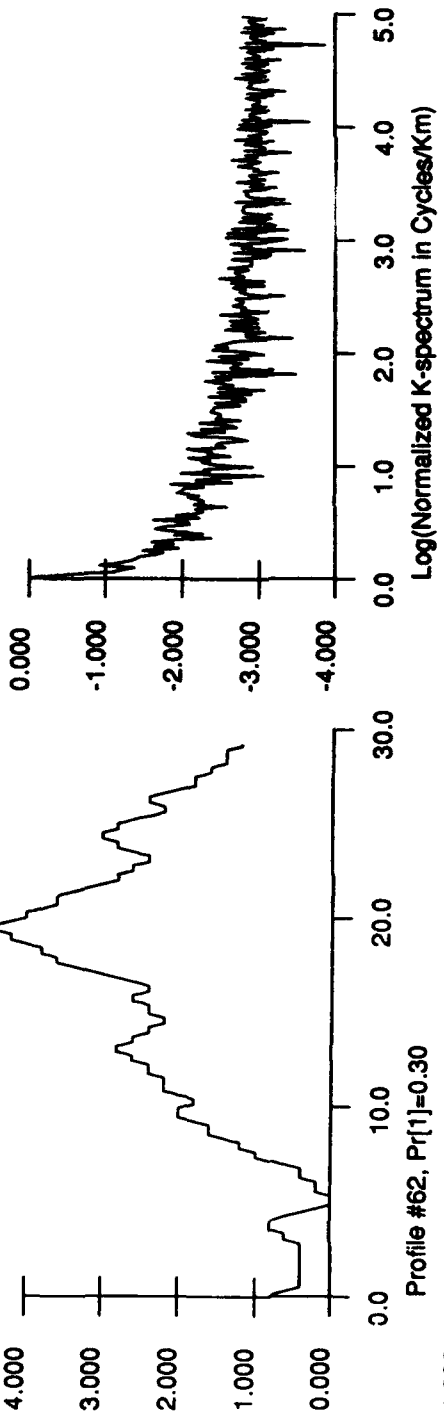
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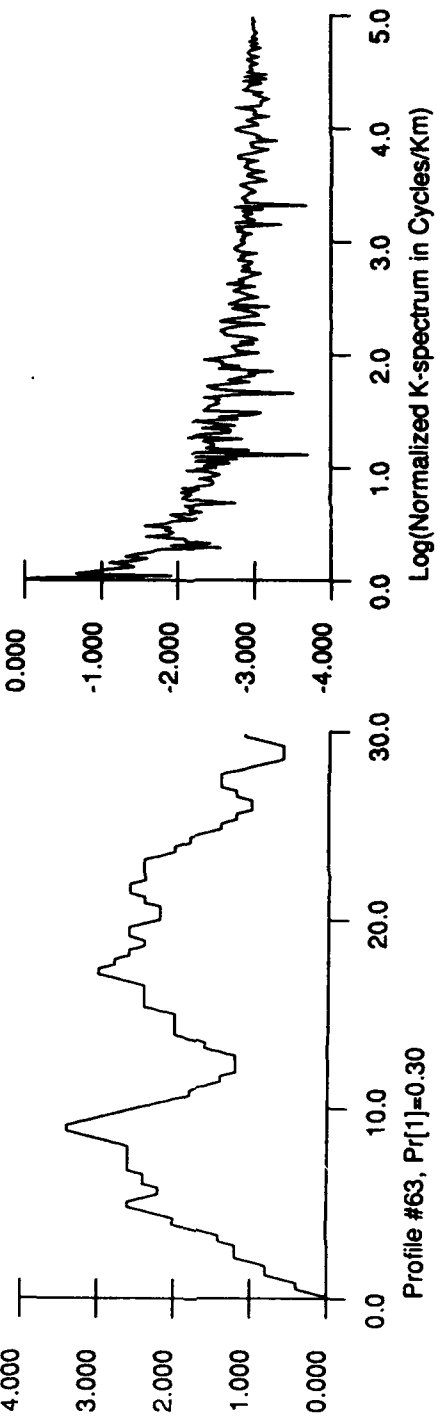
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$Pr[1] = 0.30$, Seed = 93459
[L1-jumps]/km = 0.4783
[L2-jumps]/km = 0.0400
RMS elevation = 1.0032
Durbin-Watson $\# = 0.0048$
Peak K-Spectrum = $K(0) = 1.7414$
2.88 Corners/km
(80 corners / 29.90km)
Normalized arc length= 1.198

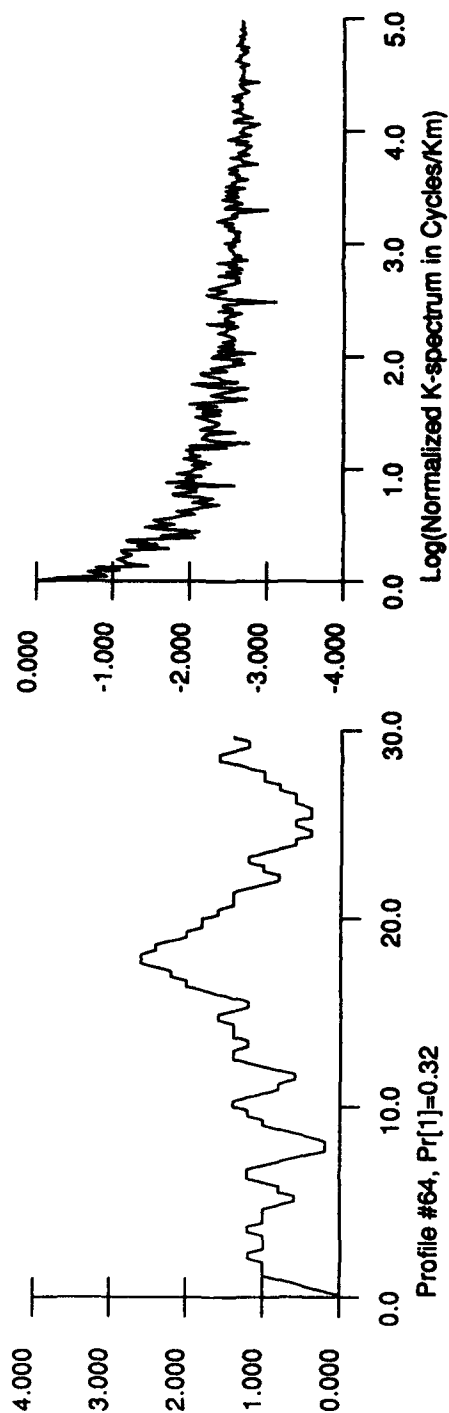


$Pr[1] = 0.30$, Seed = 93468
[L1-jumps]/km = 0.4388
[L2-jumps]/km = 0.0386
RMS elevation = 1.1804
Durbin-Watson $\# = 0.0032$
Peak K-Spectrum = $K(0) = 1.1527$
2.85 Corners/km
(78 corners / 29.30km)
Normalized arc length= 1.181

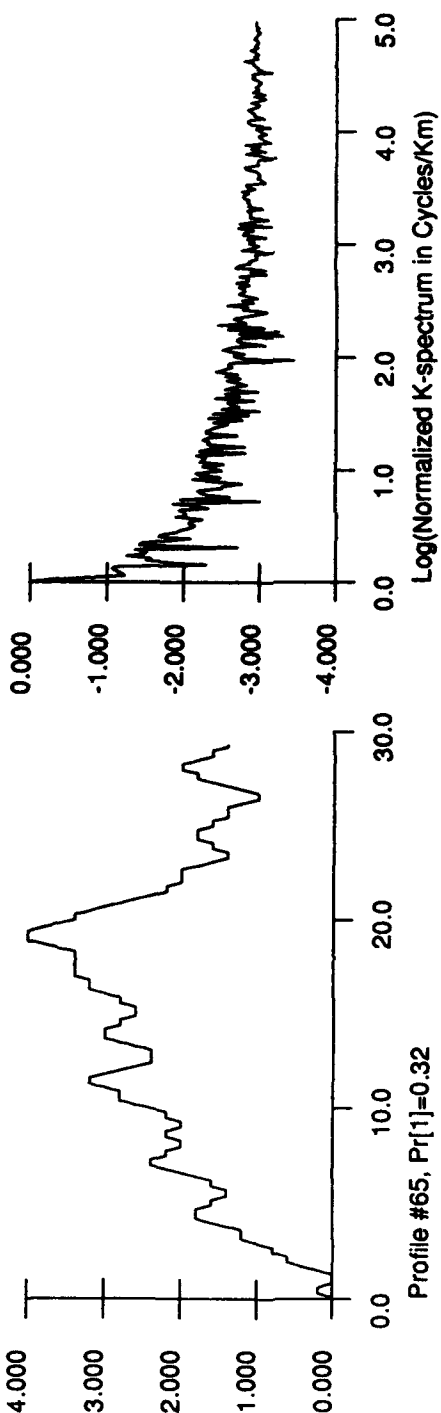


$Pr[1] = 0.30$, Seed = 93479
[L1-jumps]/km = 0.4381
[L2-jumps]/km = 0.0383
RMS elevation = 0.7448
Durbin-Watson $\# = 0.0079$
Peak K-Spectrum = $K(0) = 1.1117$
2.27 Corners/km
(88 corners / 29.90km)
Normalized arc length= 1.181

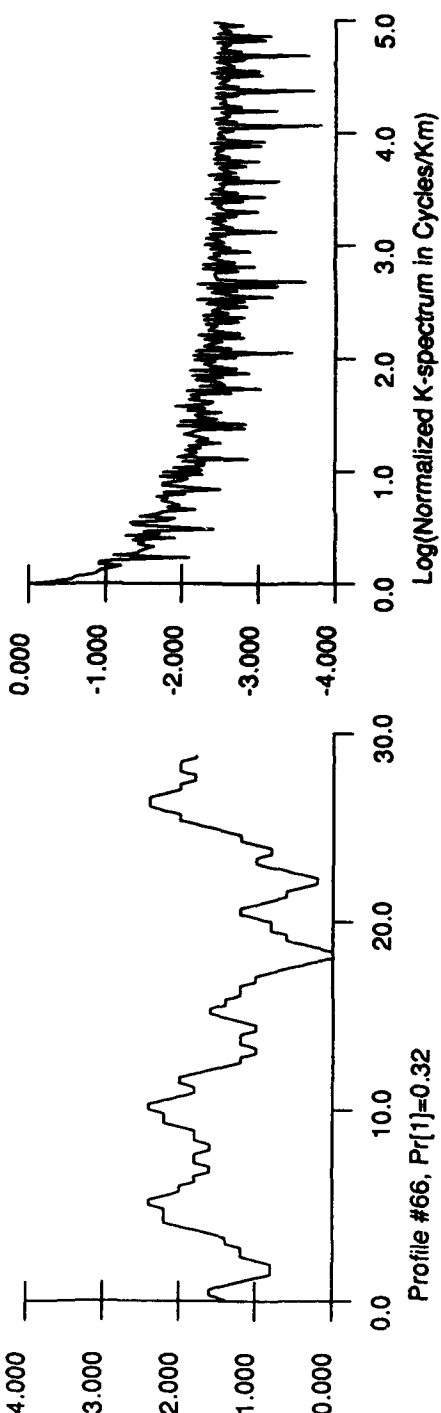
Figure 7



$Pr[1] = 0.32$, Seed = 55473
 [L1-jumps]/km = 0.4765
 [L2-jumps]/km = 0.0400
 RMS elevation = 0.5387
 Durbin-Watson # = 0.0164
 Peak K-Spectrum = $K(0) = 0.6631$
 2.68 Corners/km
 (80 corners / 29.80km)
 Normalized arc length= 1.197



$Pr[1] = 0.32$, Seed = 55499
 [L1-jumps]/km = 0.4630
 [L2-jumps]/km = 0.0405
 RMS elevation = 0.9343
 Durbin-Watson # = 0.0055
 Peak K-Spectrum = $K(0) = 1.2068$
 2.59 Corners/km
 (76 corners / 29.40km)
 Normalized arc length= 1.200



$Pr[1] = 0.32$, Seed = 55446
 [L1-jumps]/km = 0.5121
 [L2-jumps]/km = 0.0421
 RMS elevation = 0.6045
 Durbin-Watson # = 0.0140
 Peak K-Spectrum = $K(0) = 0.7949$
 2.70 Corners/km
 (78 corners / 28.90km)
 Normalized arc length= 1.212

Figure 8

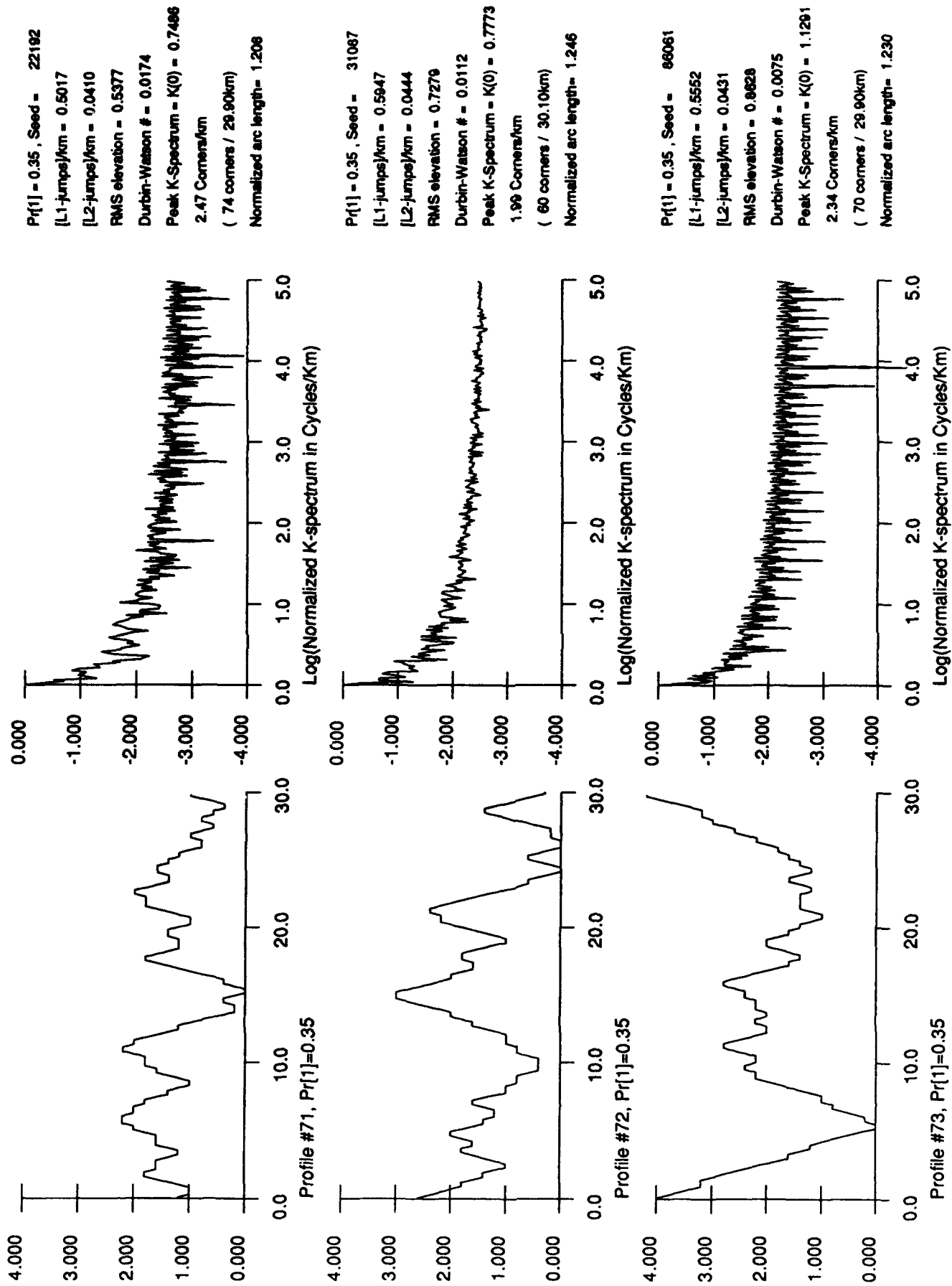
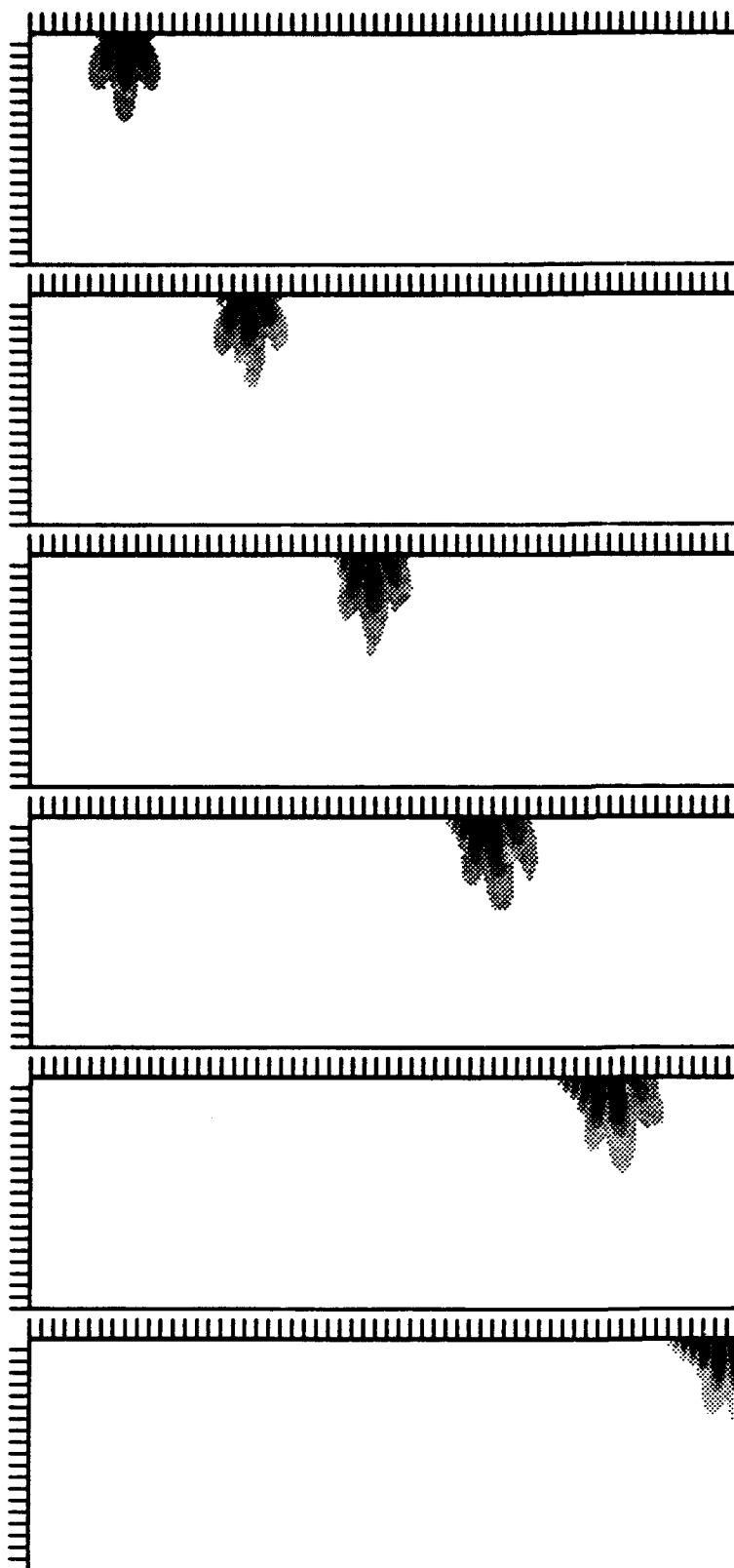


Figure 9



FD step 0
 $\text{SQRT}(V^2+H^2)$ 0.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.31808E+00

FD step 400
 $\text{SQRT}(V^2+H^2)$ 4.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.29374E+00

FD step 800
 $\text{SQRT}(V^2+H^2)$ 8.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.27150E+00

FD step 1200
 $\text{SQRT}(V^2+H^2)$ 12.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.24742E+00

FD step 1600
 $\text{SQRT}(V^2+H^2)$ 16.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.23655E+00

FD step 2000
 $\text{SQRT}(V^2+H^2)$ 20.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.23599E+00

Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]
 Profile 00 (seed 00, Pr(1)=00)

Figure 10

RATIO vers 1.5

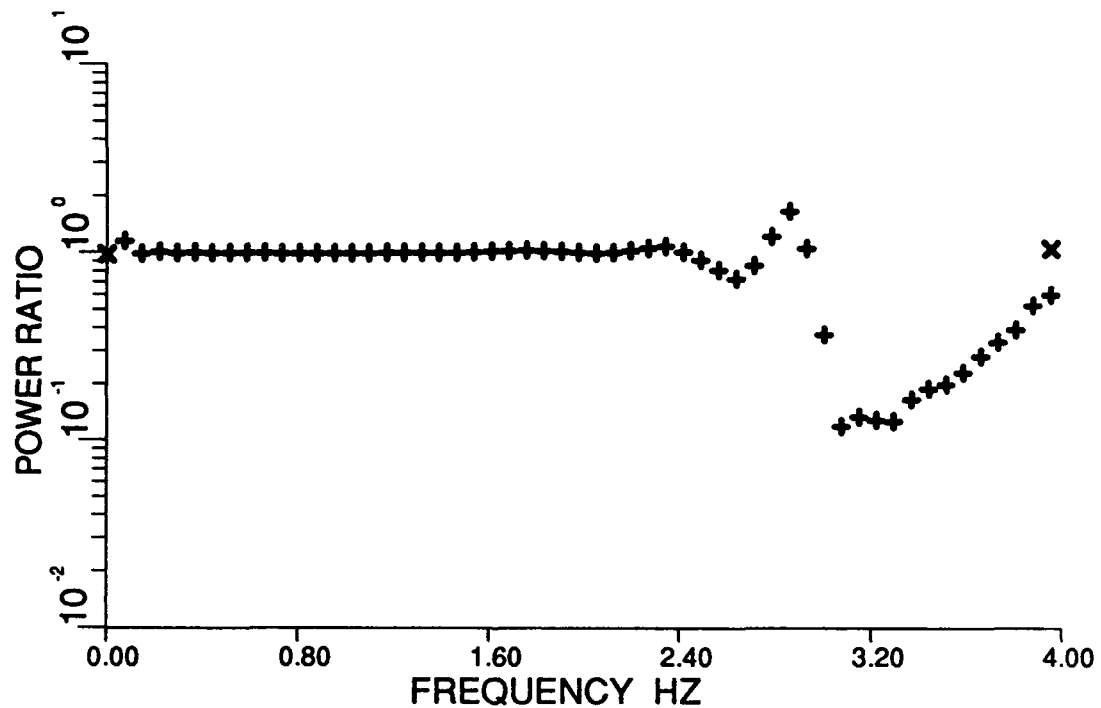
Wed Oct 27 10:16:11 1993

Model 00

NOISE POWER NOT SUBTRACTED FROM SIGNAL POWER

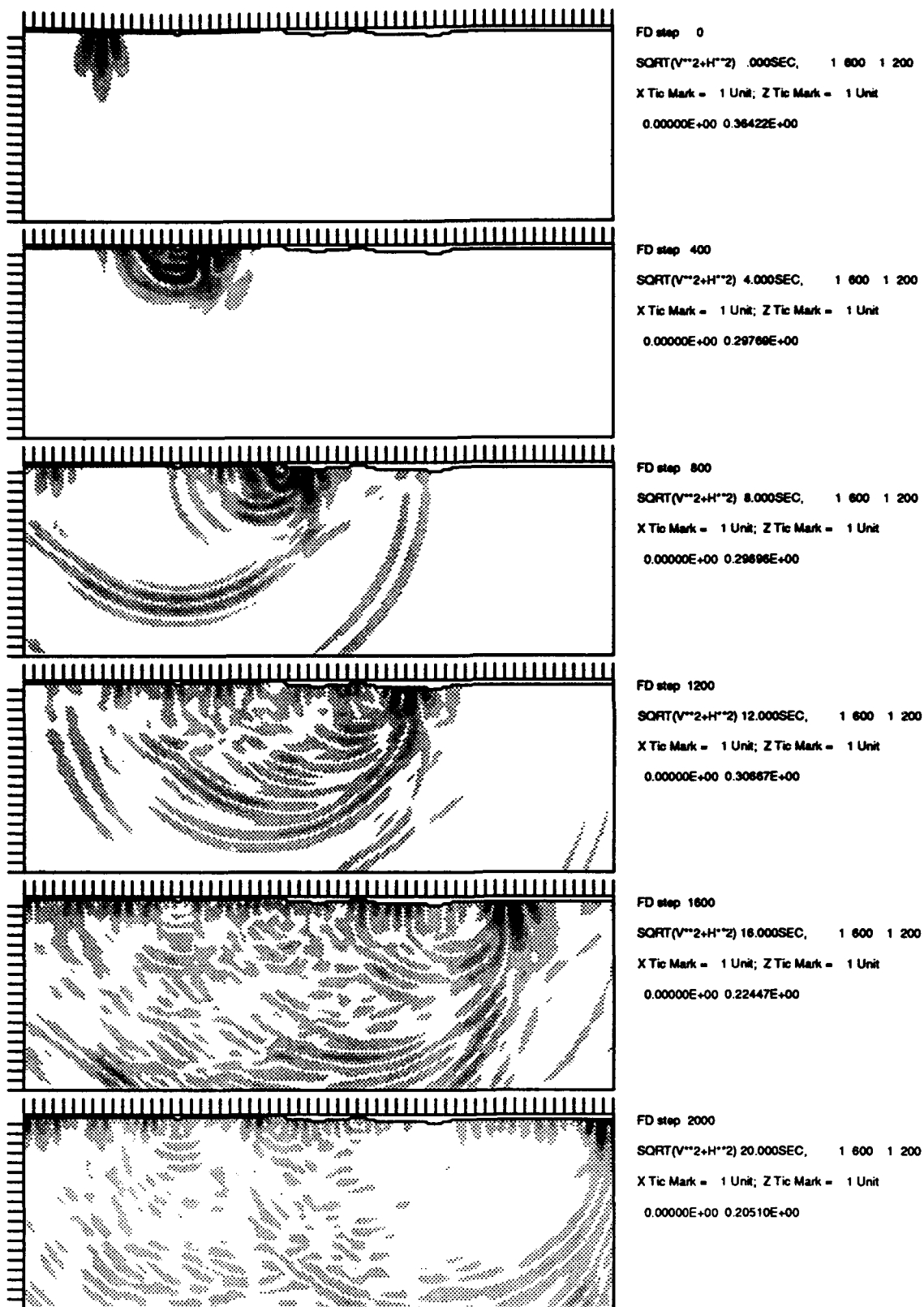
S/N POWER THRESHOLD = 2.0 N

NO SMOOTHING



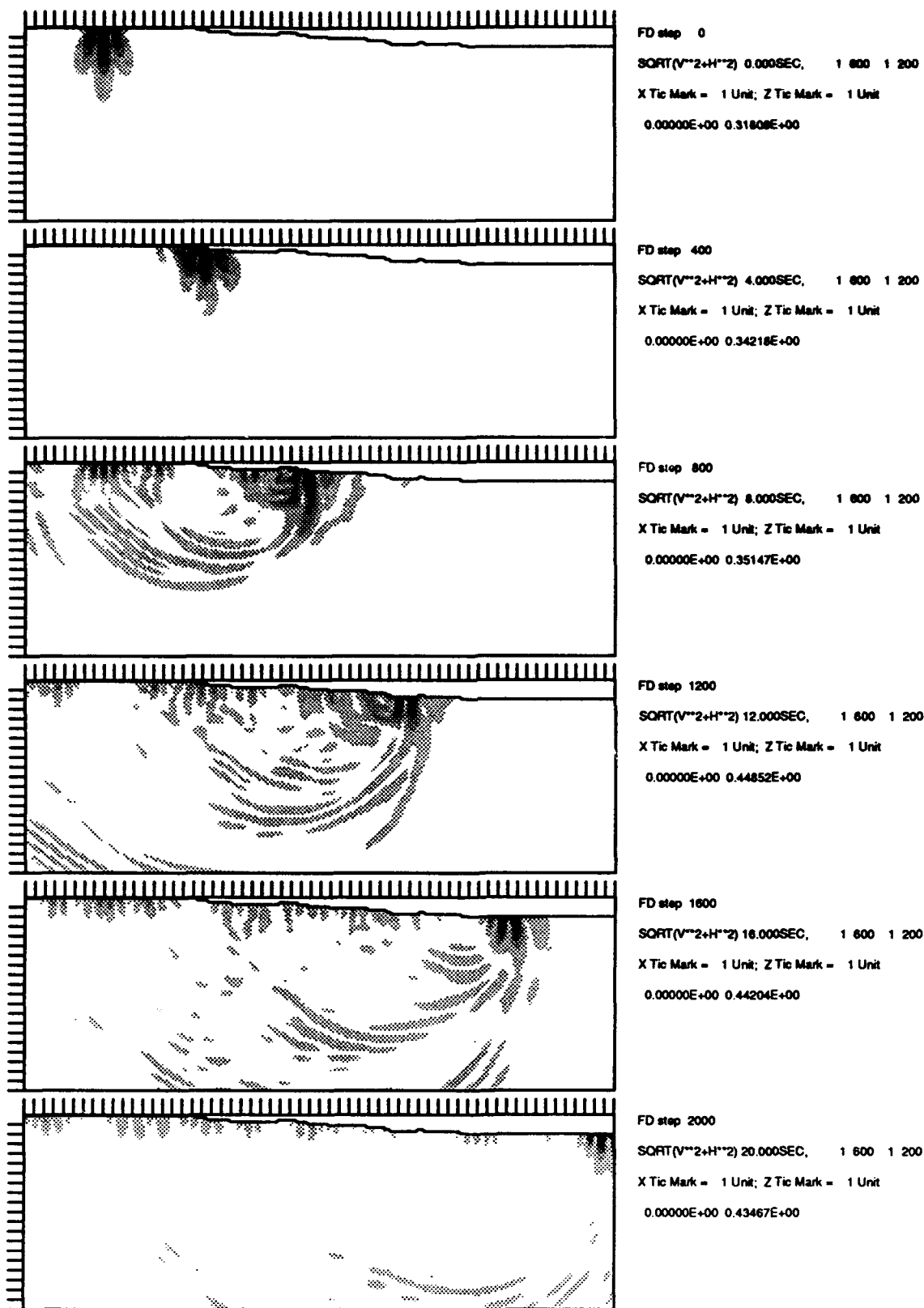
FREQ BAND	SLOPE	+/-	Y INTERC	AV INTEG	AV RATIO	SD
0.75-1.25	5.869e-03	1.118e-03	9.776e-01	-3.947e-03	-3.798e-03	1.040e-03
0.50-1.50	1.023e-03	1.011e-03	9.907e-01	-3.047e-03	-3.058e-03	1.201e-03
0.01-1.00	-3.351e-02	1.422e-02	1.047e+00	2.943e-03	2.685e-03	1.747e-02
1.00-2.00	1.037e-02	3.236e-03	9.670e-01	9.790e-04	9.942e-04	4.884e-03
0.50-3.00	5.904e-03	1.235e-02	9.772e-01	3.371e-04	1.670e-04	5.272e-02

Figure 11



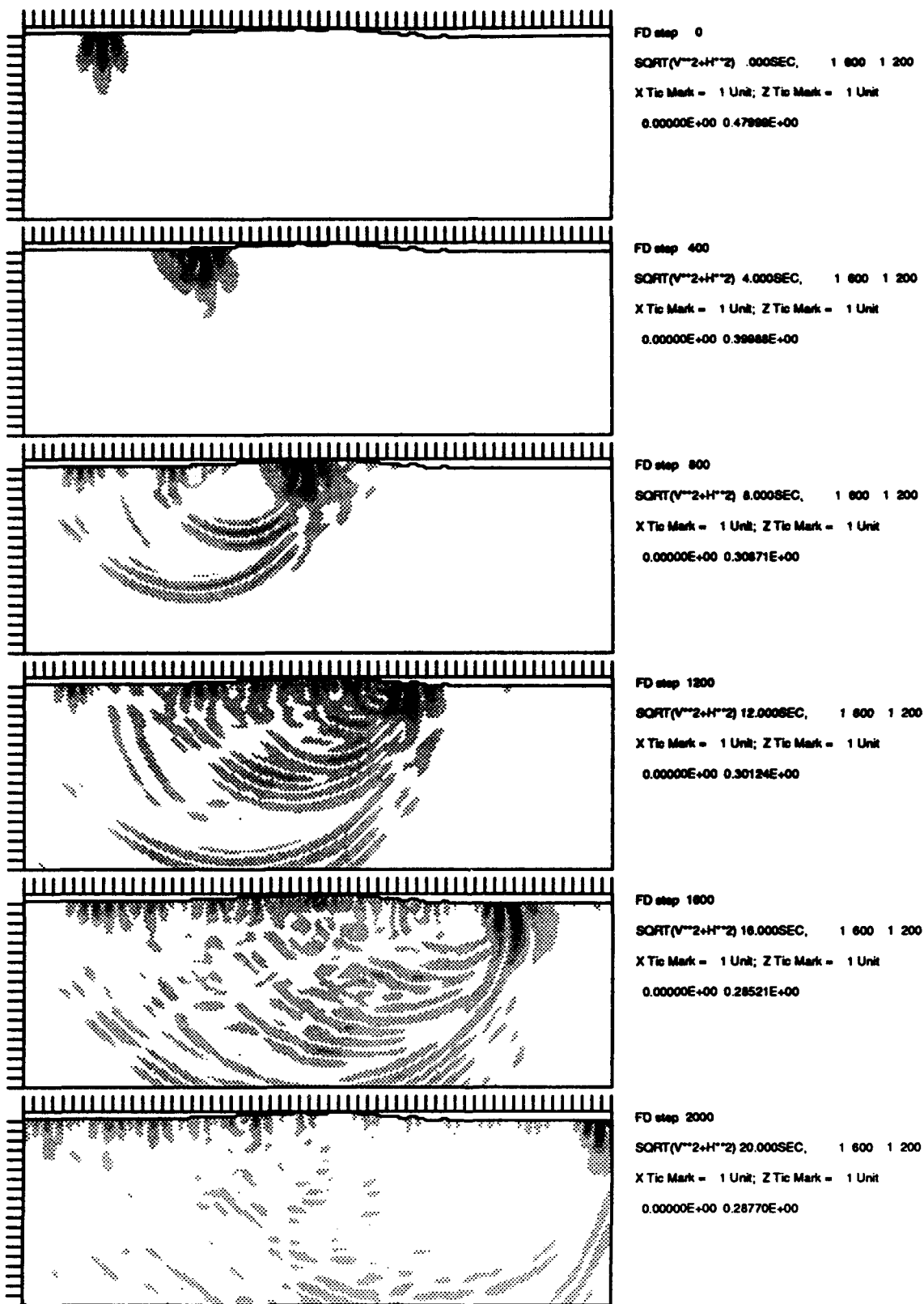
Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]
 Profile 11 (seed 22887, Pr(1)=0.05)

Figure 12



Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]
 Profile 12 (seed 22892, Pr(1)=0.05)

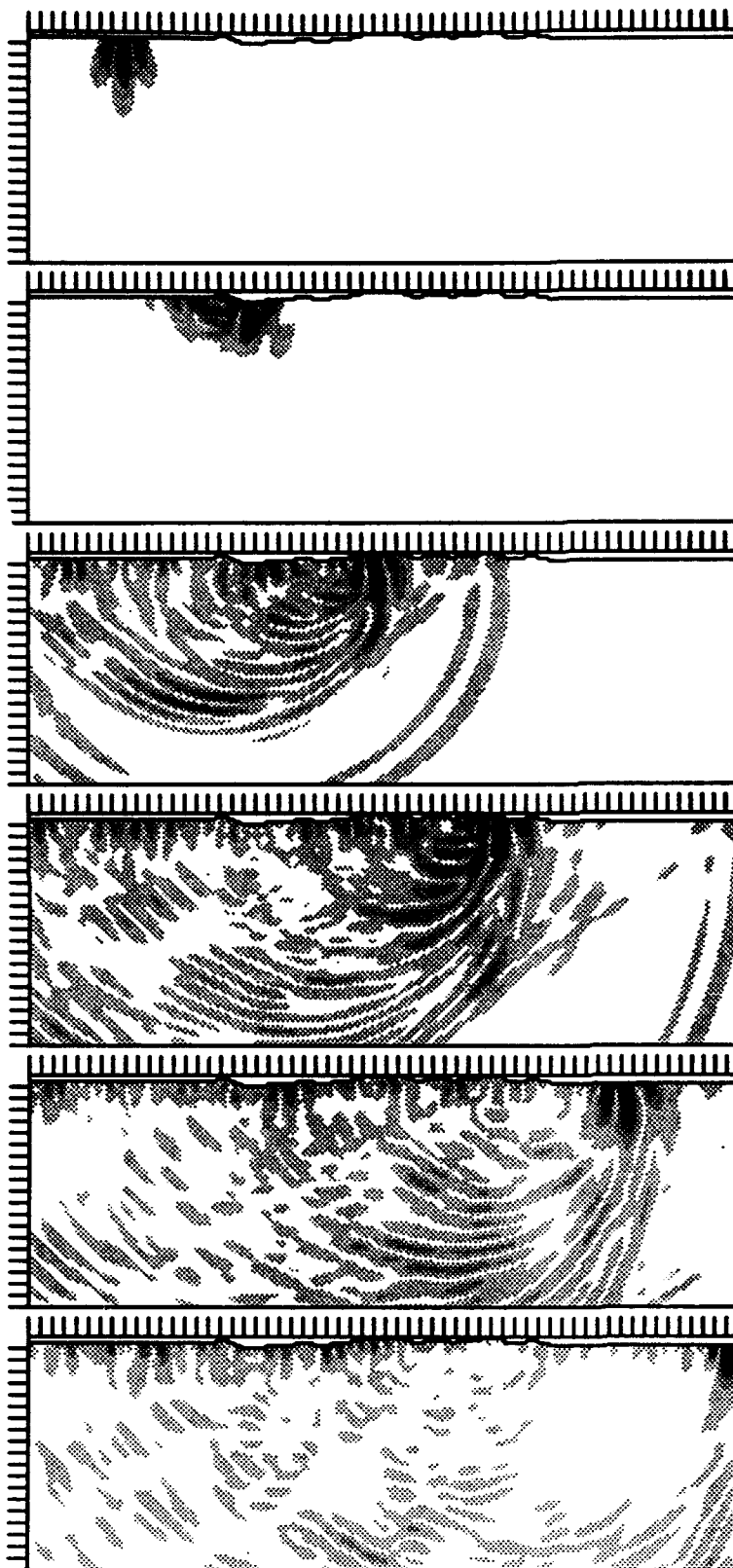
Figure 13



Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]

Profile 13 (seed 85995, Pr(1)=0.05)

Figure 14



FD step 0

$\text{SQRT}(V^2+H^2)$.000SEC, 1 600 1 200

X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit

0.00000E+00 0.41788E+00

FD step 400

$\text{SQRT}(V^2+H^2)$ 4.000SEC, 1 600 1 200

X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit

0.00000E+00 0.49508E+00

FD step 800

$\text{SQRT}(V^2+H^2)$ 8.000SEC, 1 600 1 200

X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit

0.00000E+00 0.27865E+00

FD step 1200

$\text{SQRT}(V^2+H^2)$ 12.000SEC, 1 600 1 200

X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit

0.00000E+00 0.21286E+00

FD step 1600

$\text{SQRT}(V^2+H^2)$ 16.000SEC, 1 600 1 200

X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit

0.00000E+00 0.21653E+00

FD step 2000

$\text{SQRT}(V^2+H^2)$ 20.000SEC, 1 600 1 200

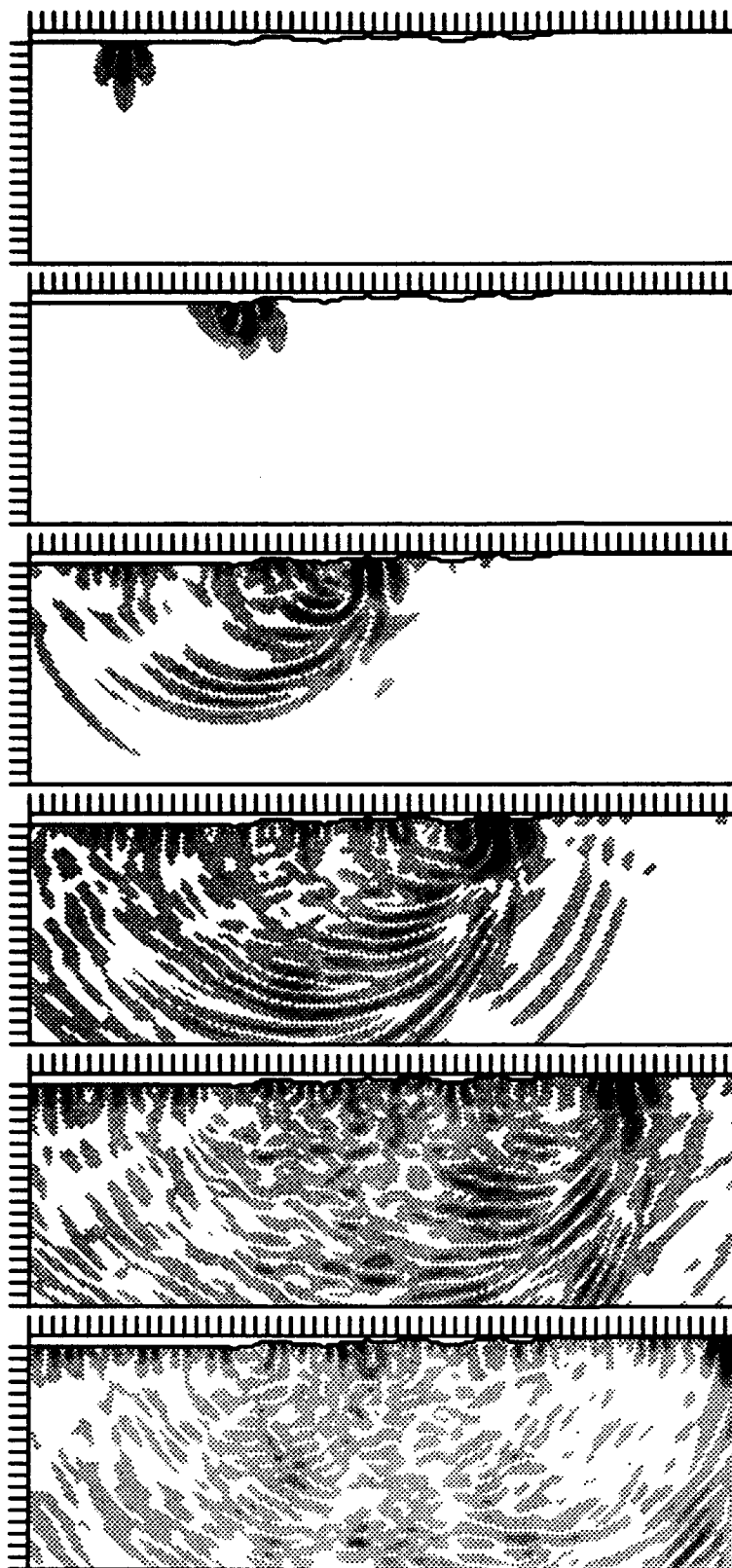
X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit

0.00000E+00 0.19194E+00

Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]

Profile 14 (seed 91333, Pr(1)=0.07)

Figure 15



FD step 0
 $\text{SQRT}(V^2+H^2)$.000SEC, 1 600 1 200
 X Tie Mark = 1 Unit; Z Tie Mark = 1 Unit
 0.00000E+00 0.55123E+00

FD step 400
 $\text{SQRT}(V^2+H^2)$ 4.000SEC, 1 600 1 200
 X Tie Mark = 1 Unit; Z Tie Mark = 1 Unit
 0.00000E+00 0.55875E+00

FD step 800
 $\text{SQRT}(V^2+H^2)$ 8.000SEC, 1 600 1 200
 X Tie Mark = 1 Unit; Z Tie Mark = 1 Unit
 0.00000E+00 0.37207E+00

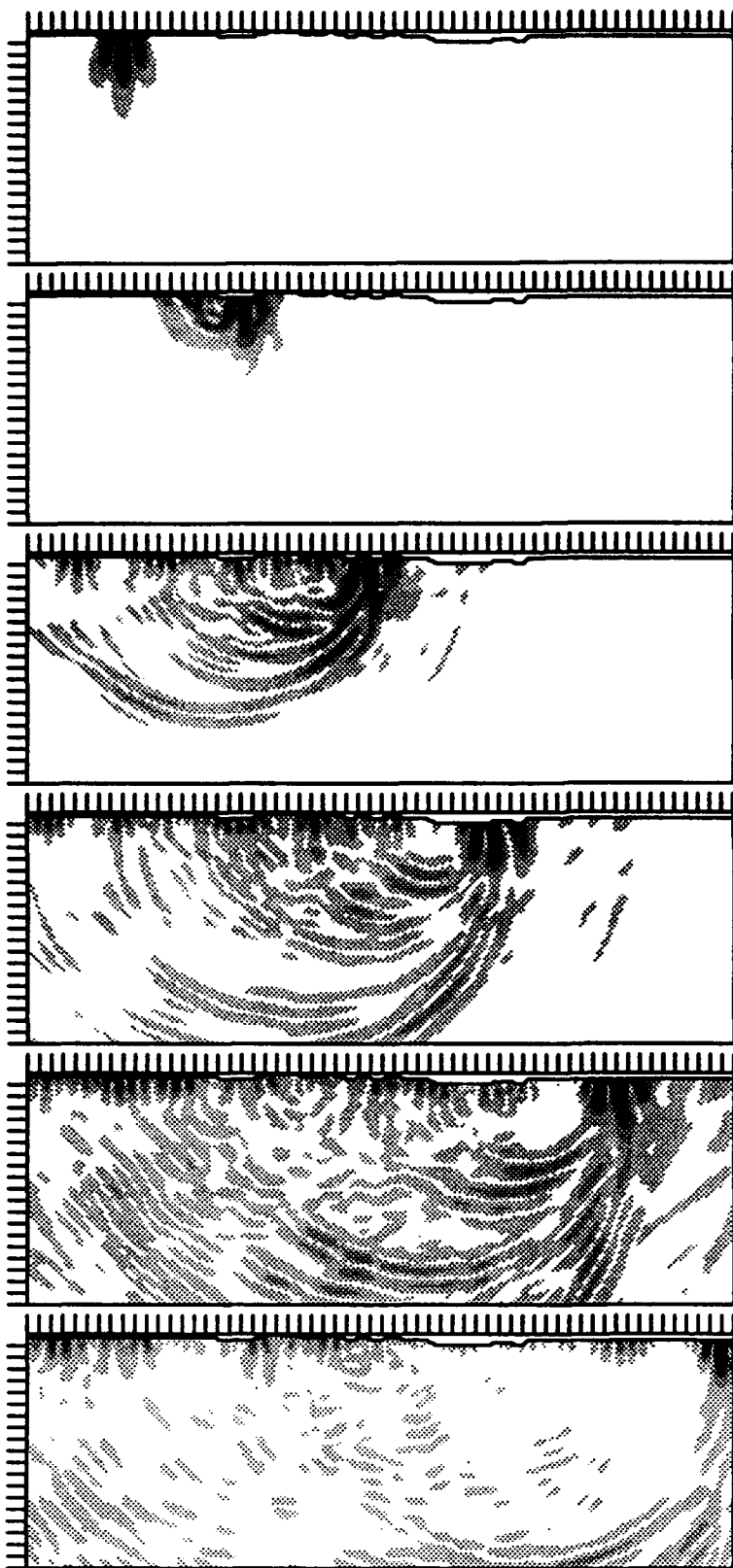
FD step 1200
 $\text{SQRT}(V^2+H^2)$ 12.000SEC, 1 600 1 200
 X Tie Mark = 1 Unit; Z Tie Mark = 1 Unit
 0.00000E+00 0.23876E+00

FD step 1600
 $\text{SQRT}(V^2+H^2)$ 16.000SEC, 1 600 1 200
 X Tie Mark = 1 Unit; Z Tie Mark = 1 Unit
 0.00000E+00 0.17323E+00

FD step 2000
 $\text{SQRT}(V^2+H^2)$ 20.000SEC, 1 600 1 200
 X Tie Mark = 1 Unit; Z Tie Mark = 1 Unit
 0.00000E+00 0.15070E+00

Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]
 Profile 15 (seed 91350, Pr(1)=0.07)

Figure 16



FD step 0
 $\text{SQRT}(V^2+H^2)$ 0.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.36422E+00

FD step 400
 $\text{SQRT}(V^2+H^2)$ 4.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.37715E+00

FD step 800
 $\text{SQRT}(V^2+H^2)$ 8.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.28420E+00

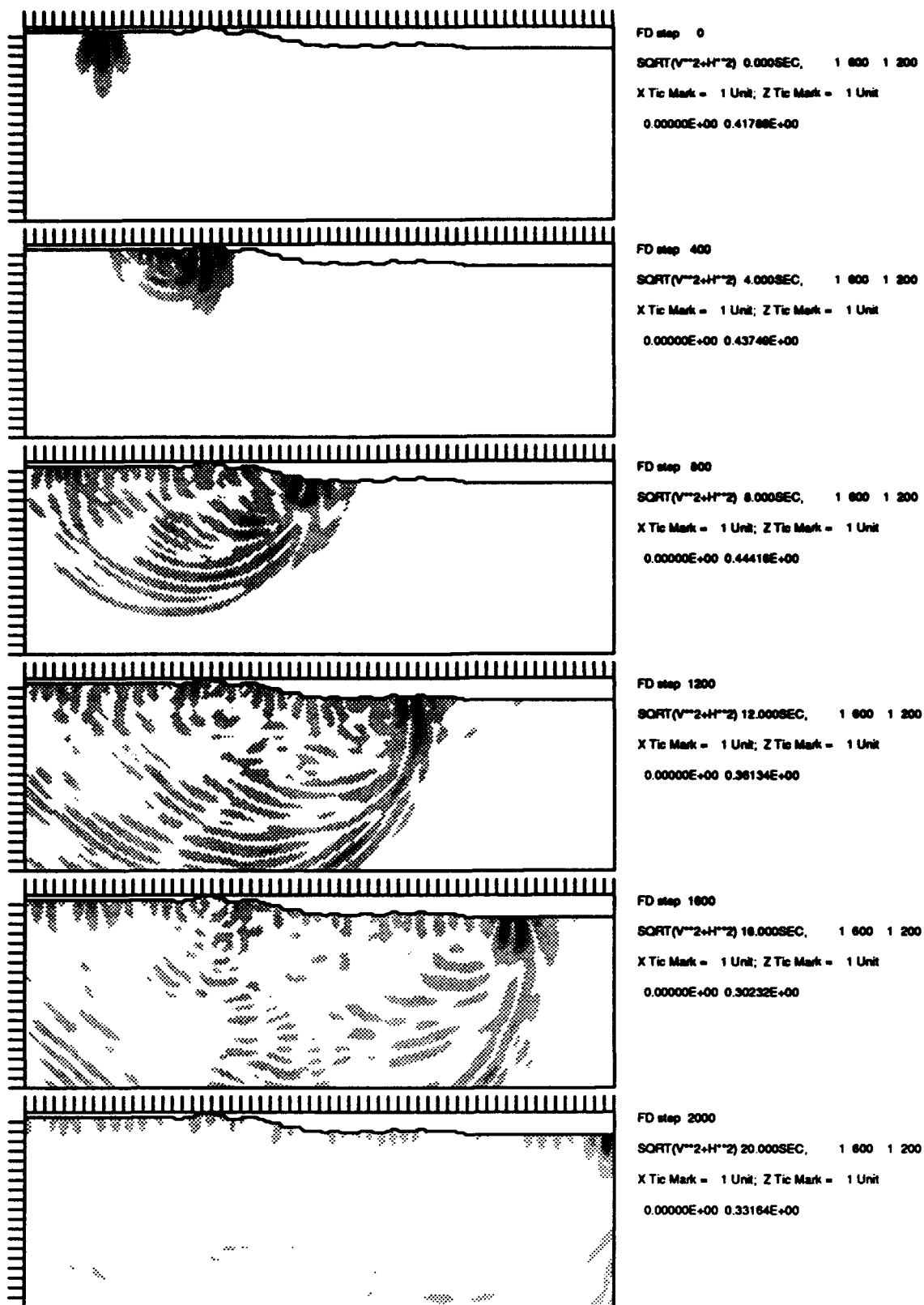
FD step 1200
 $\text{SQRT}(V^2+H^2)$ 12.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.30135E+00

FD step 1600
 $\text{SQRT}(V^2+H^2)$ 16.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.20114E+00

FD step 2000
 $\text{SQRT}(V^2+H^2)$ 20.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.19439E+00

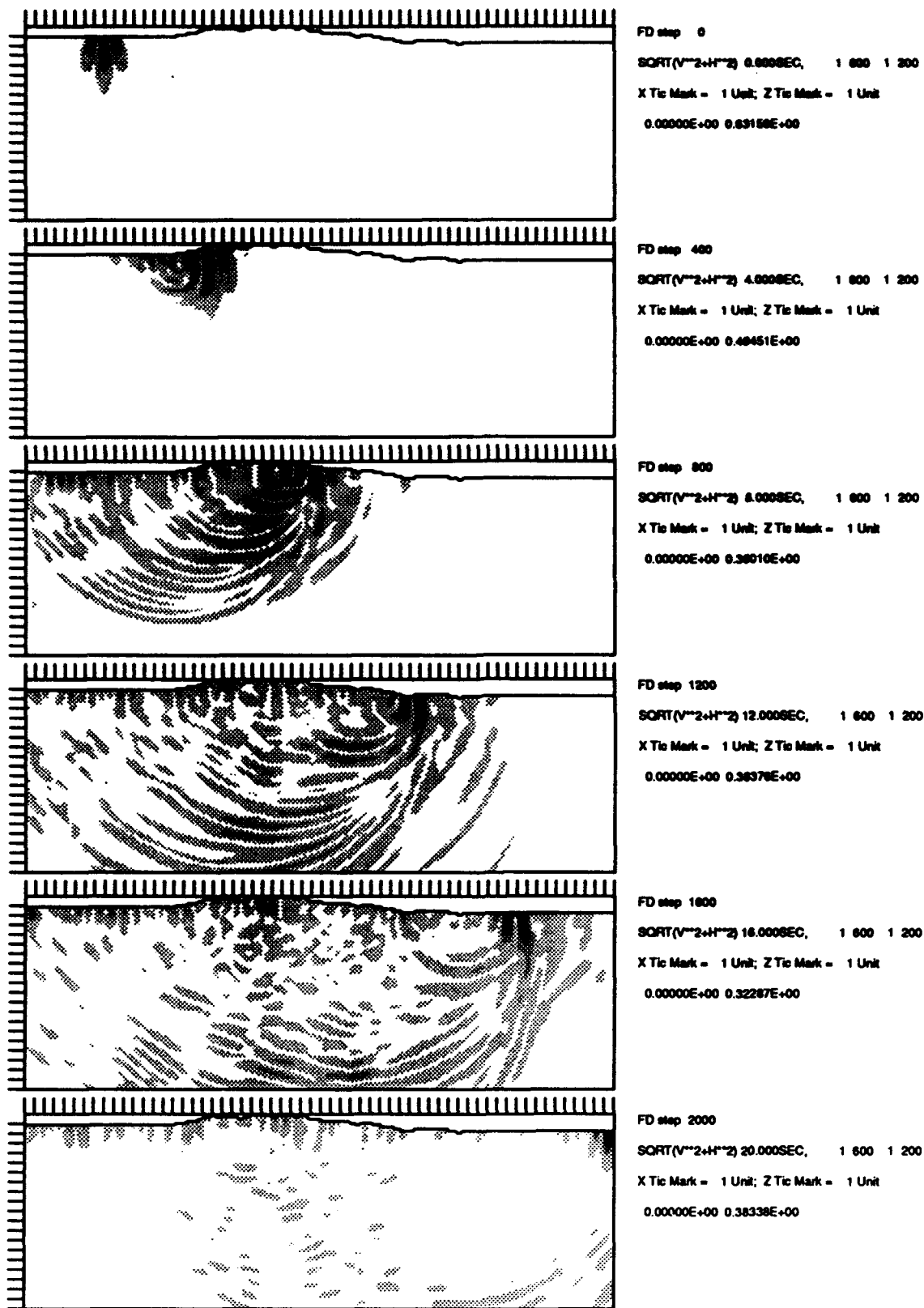
Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]
 Profile 16 (seed 91285, Pr(1)=0.07)

Figure 17



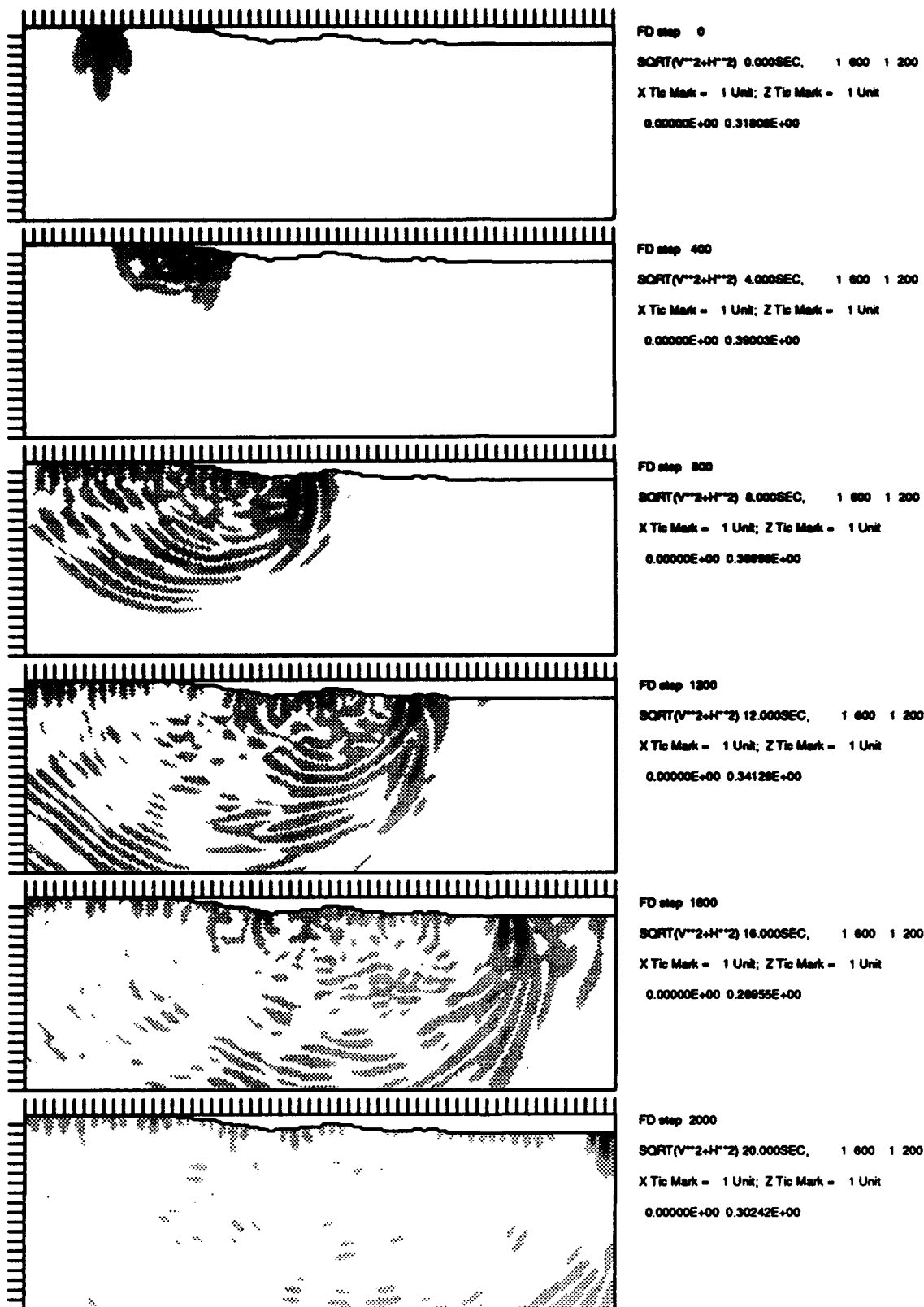
Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]
 Profile 21 (seed 93337, Pr(1)=0.10)

Figure 18



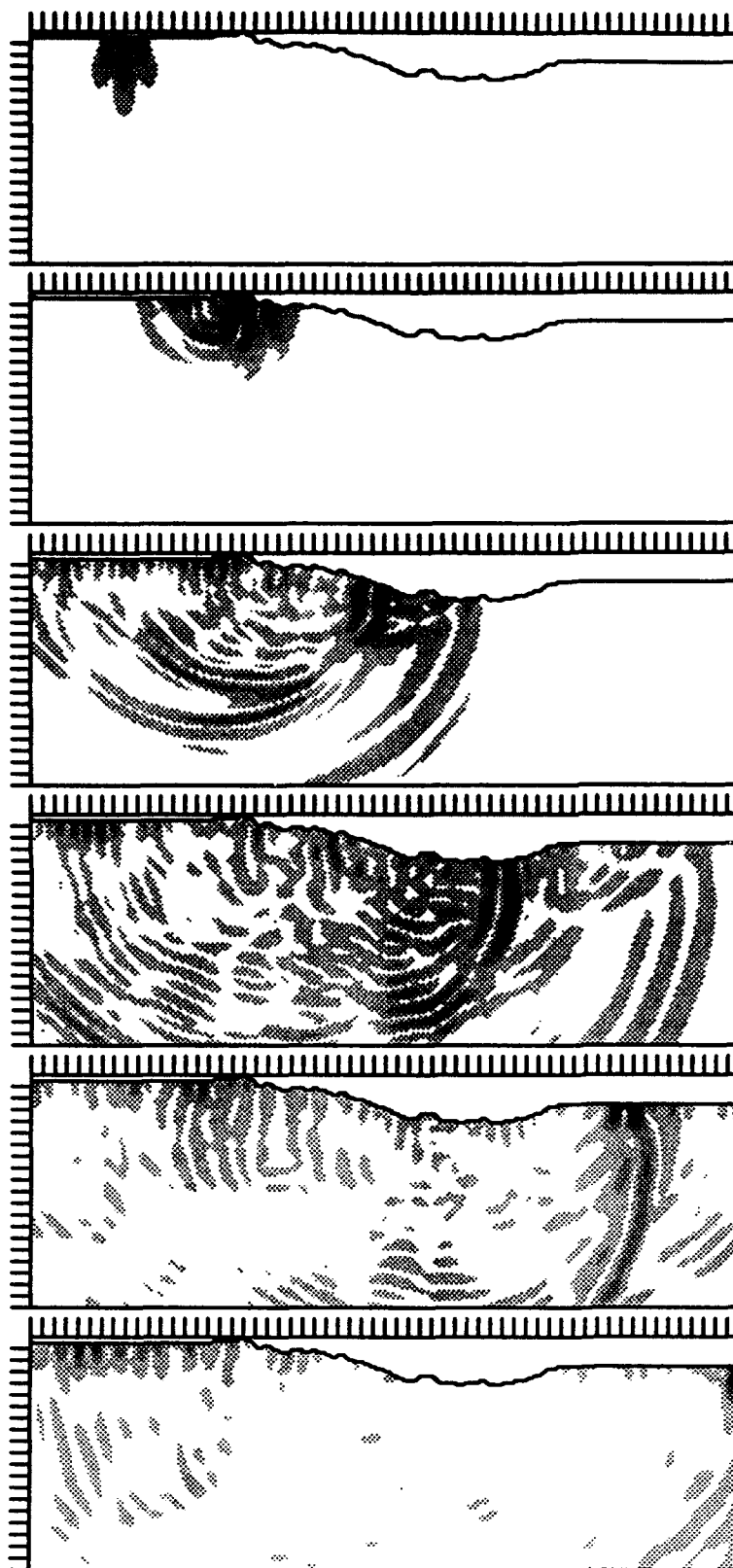
Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]
 Profile 22 (seed 93347, Pr(1)=0.10)

Figure 19



Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]
 Profile 23 (seed 93356, Pr(1)=0.10)

Figure 20



FD step 0
 $\text{SQRT}(V^2+H^2)$.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.41788E+00

FD step 400
 $\text{SQRT}(V^2+H^2)$ 4.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.37320E+00

FD step 800
 $\text{SQRT}(V^2+H^2)$ 8.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.29371E+00

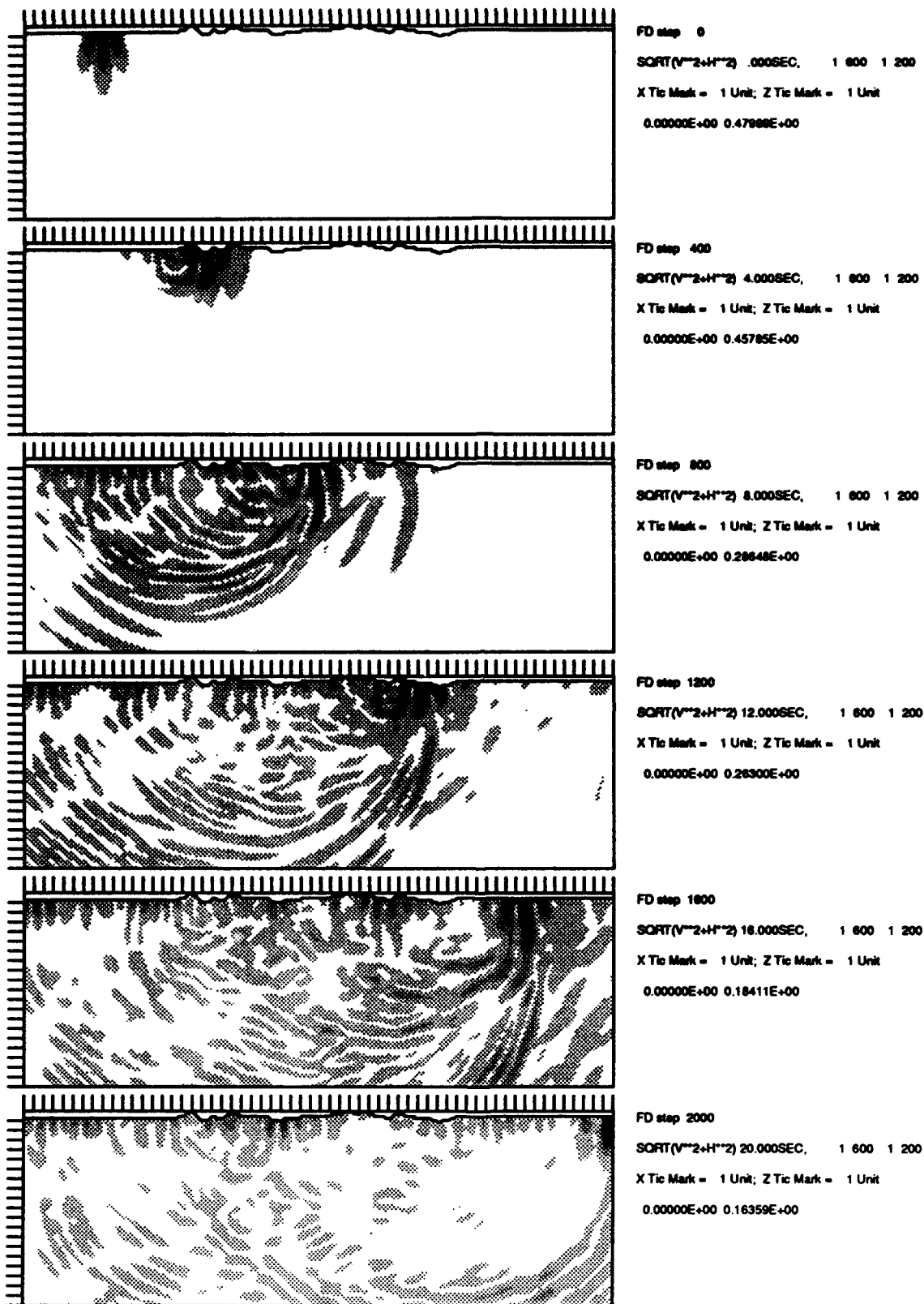
FD step 1200
 $\text{SQRT}(V^2+H^2)$ 12.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.19162E+00

FD step 1600
 $\text{SQRT}(V^2+H^2)$ 16.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.20056E+00

FD step 2000
 $\text{SQRT}(V^2+H^2)$ 20.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.17620E+00

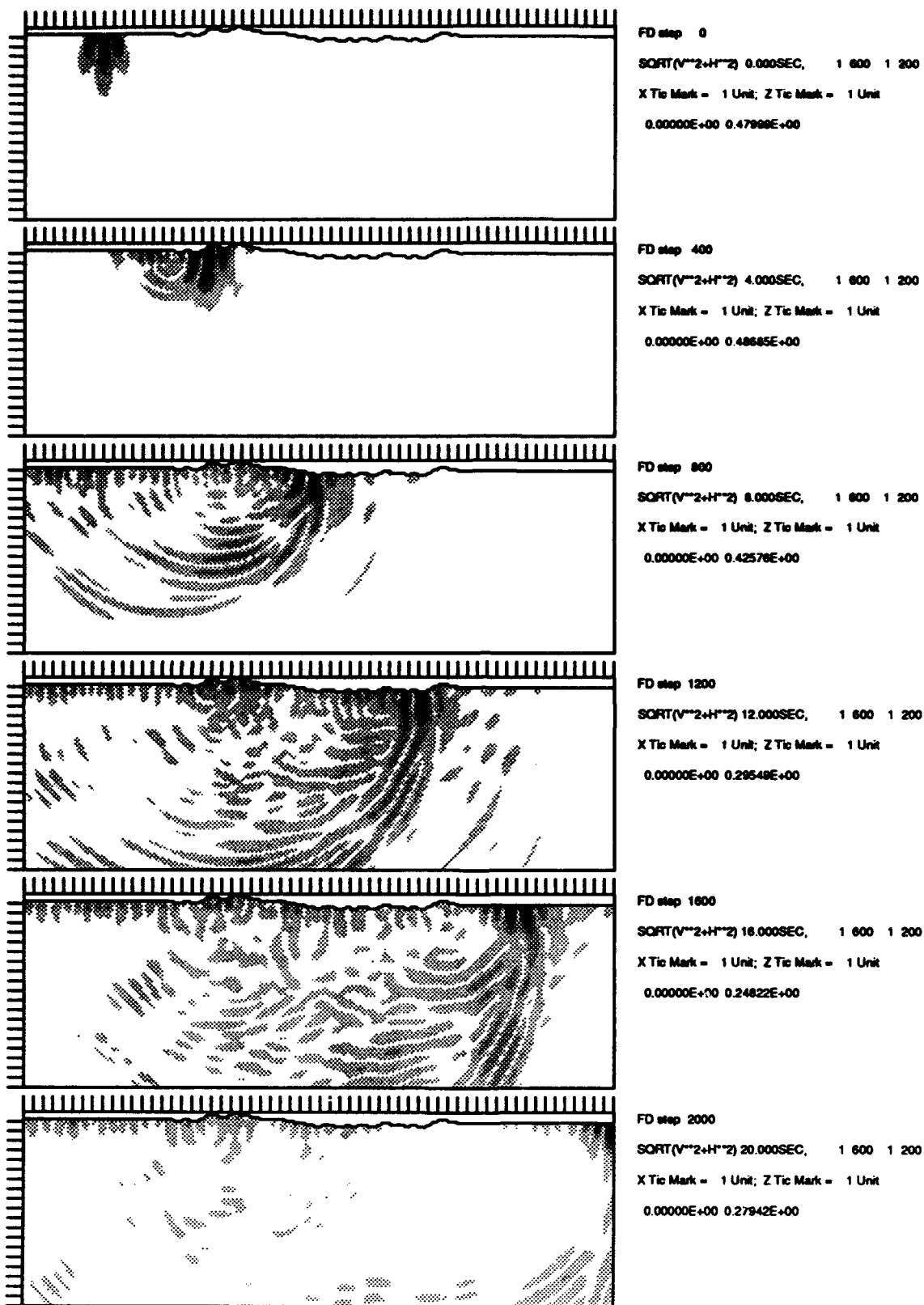
Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]
 Profile 31 (seed 748546615, Pr(1)=0.15)

Figure 21



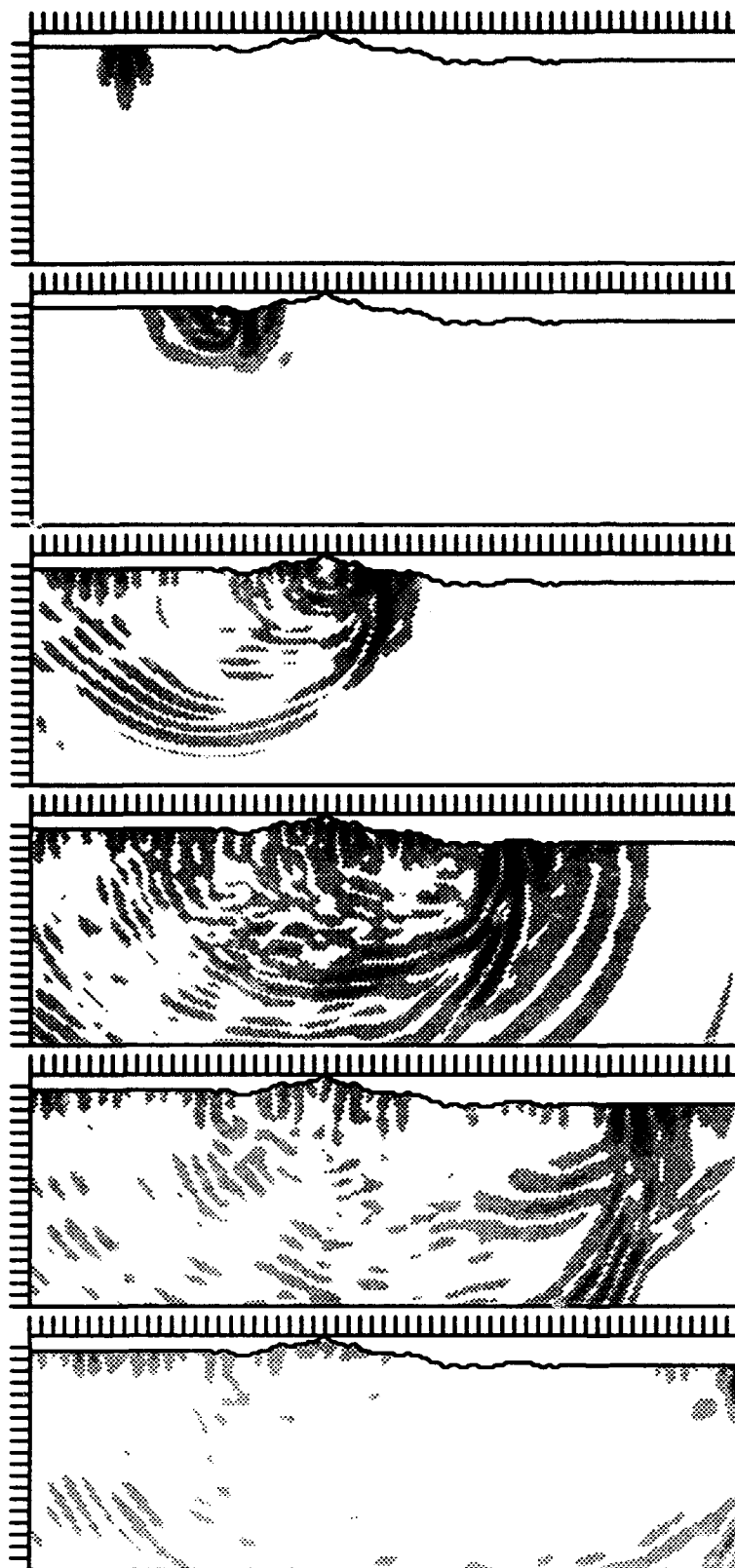
Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]
 Profile 32 (seed 20333, Pr(1)=0.15)

Figure 22



Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]
 Profile 33 (seed 86016, Pr(1)=0.15)

Figure 23



FD step 0
 SORT(V**2+H**2) .000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.71954E+00

FD step 400
 SORT(V**2+H**2) 4.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.60252E+00

FD step 800
 SORT(V**2+H**2) 8.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.43803E+00

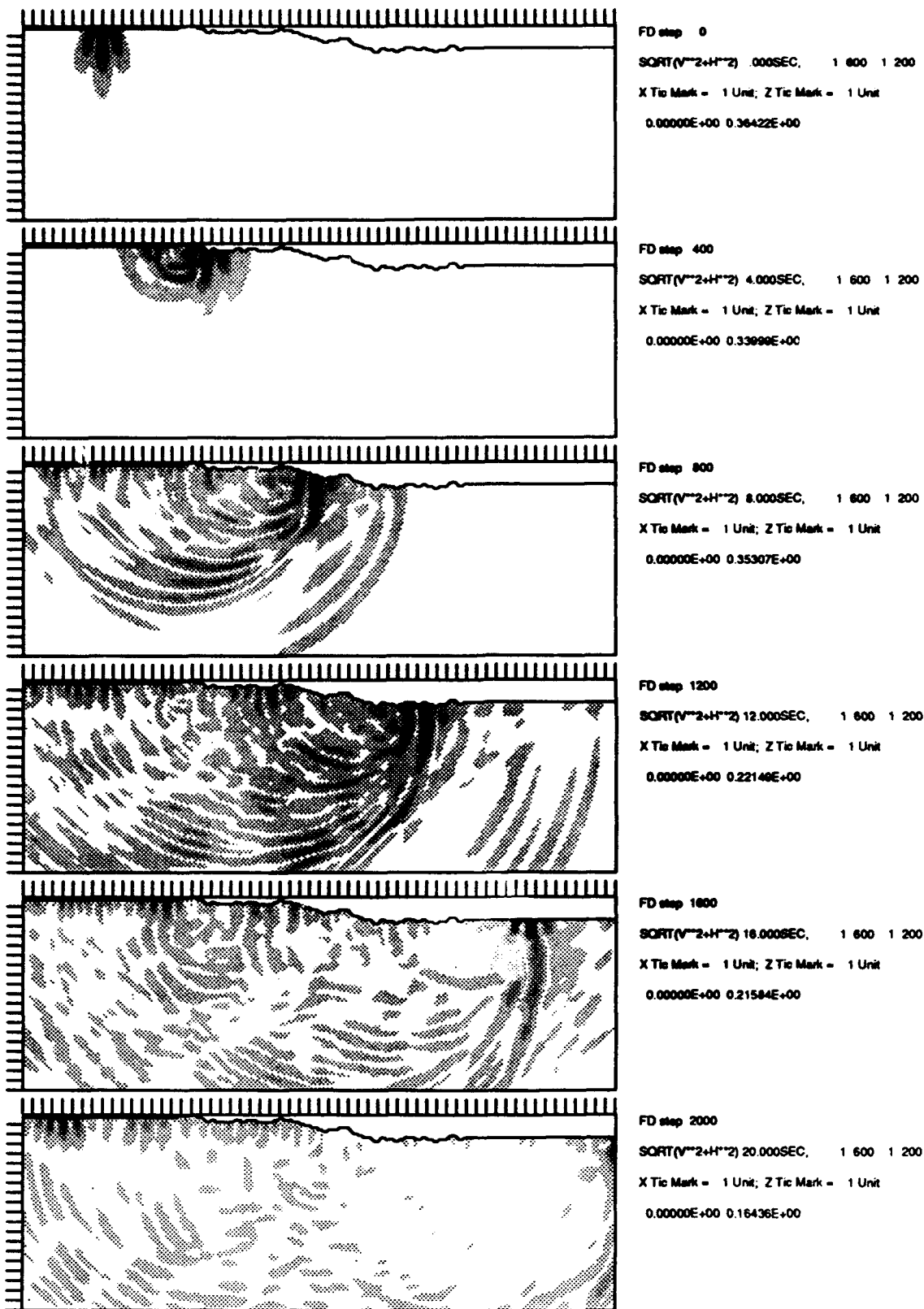
FD step 1200
 SORT(V**2+H**2) 12.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.22488E+00

FD step 1600
 SORT(V**2+H**2) 16.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.24798E+00

FD step 2000
 SORT(V**2+H**2) 20.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.23157E+00

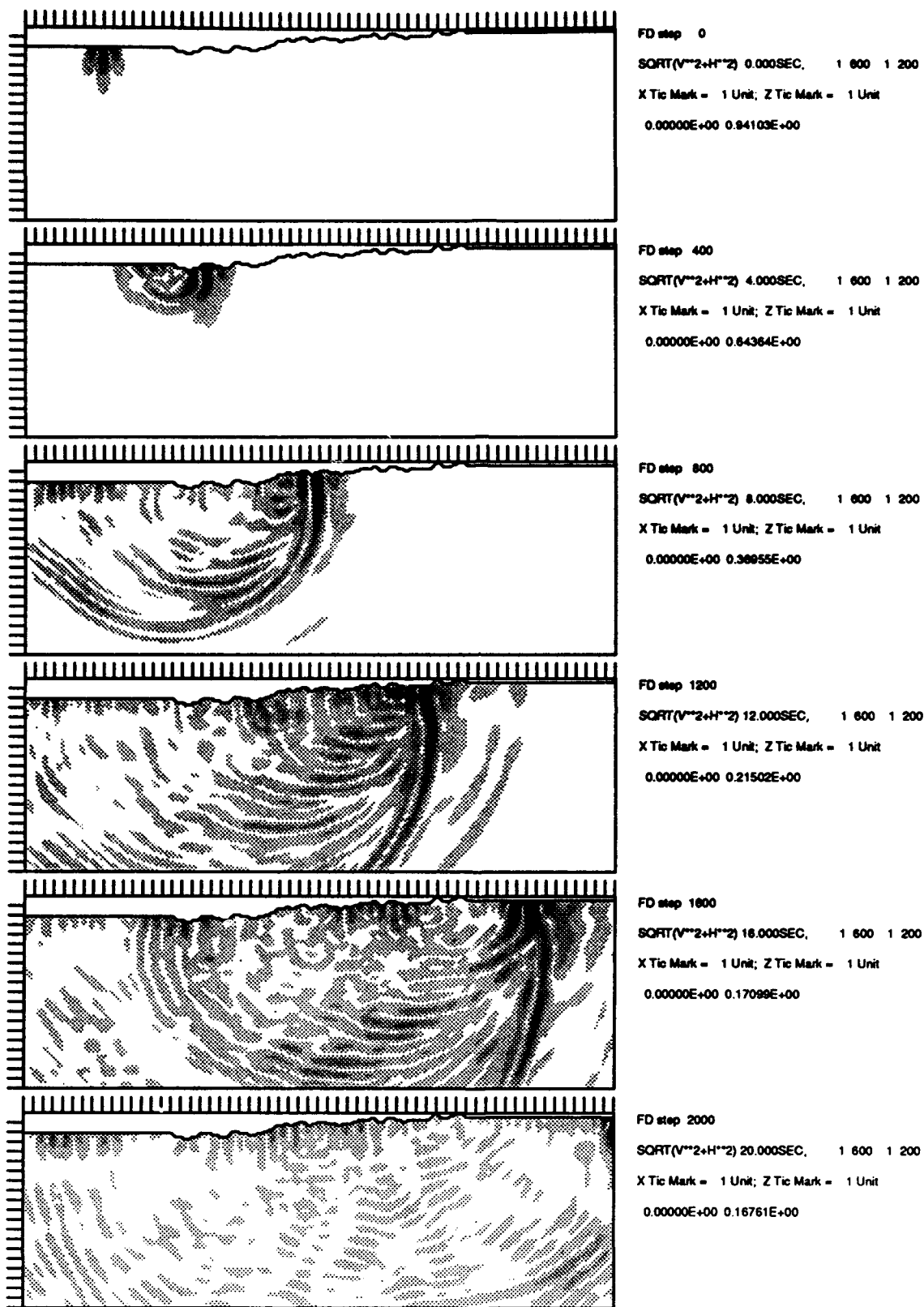
Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]
 Profile 41 (seed 93397, Pr(1)=0.20)

Figure 24



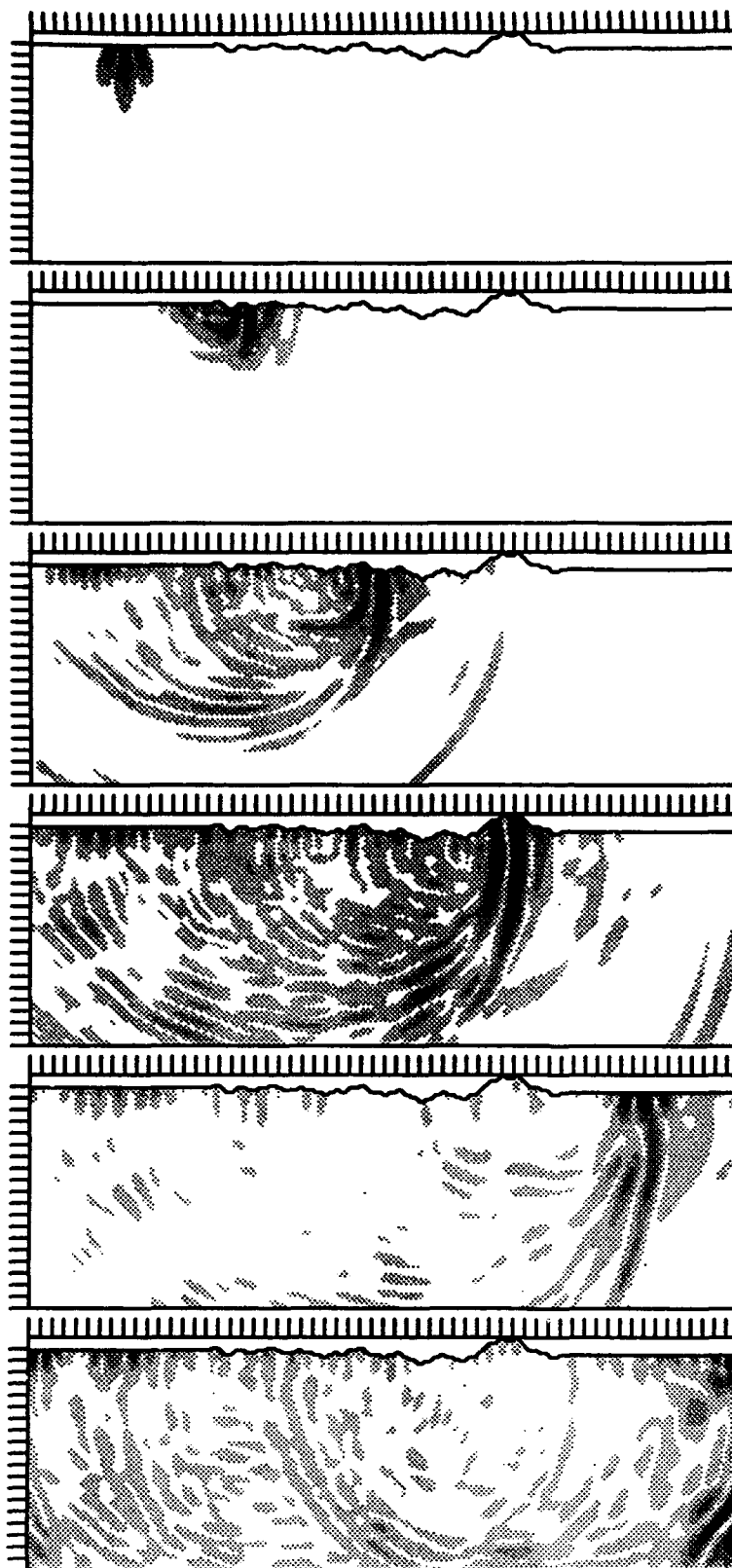
Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]
 Profile 42 (seed 93407, Pr(1)=0.20)

Figure 25



Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]
 Profile 43 (seed 12345, Pr(1)=0.20)

Figure 26



FD step 0

$\text{SQRT}(V^2+H^2)$.000SEC, 1 600 1 200

X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit

0.00000E+00 0.63158E+00

FD step 400

$\text{SQRT}(V^2+H^2)$ 4.000SEC, 1 600 1 200

X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit

0.00000E+00 0.55110E+00

FD step 800

$\text{SQRT}(V^2+H^2)$ 8.000SEC, 1 600 1 200

X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit

0.00000E+00 0.34011E+00

FD step 1200

$\text{SQRT}(V^2+H^2)$ 12.000SEC, 1 600 1 200

X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit

0.00000E+00 0.18248E+00

FD step 1600

$\text{SQRT}(V^2+H^2)$ 16.000SEC, 1 600 1 200

X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit

0.00000E+00 0.25548E+00

FD step 2000

$\text{SQRT}(V^2+H^2)$ 20.000SEC, 1 600 1 200

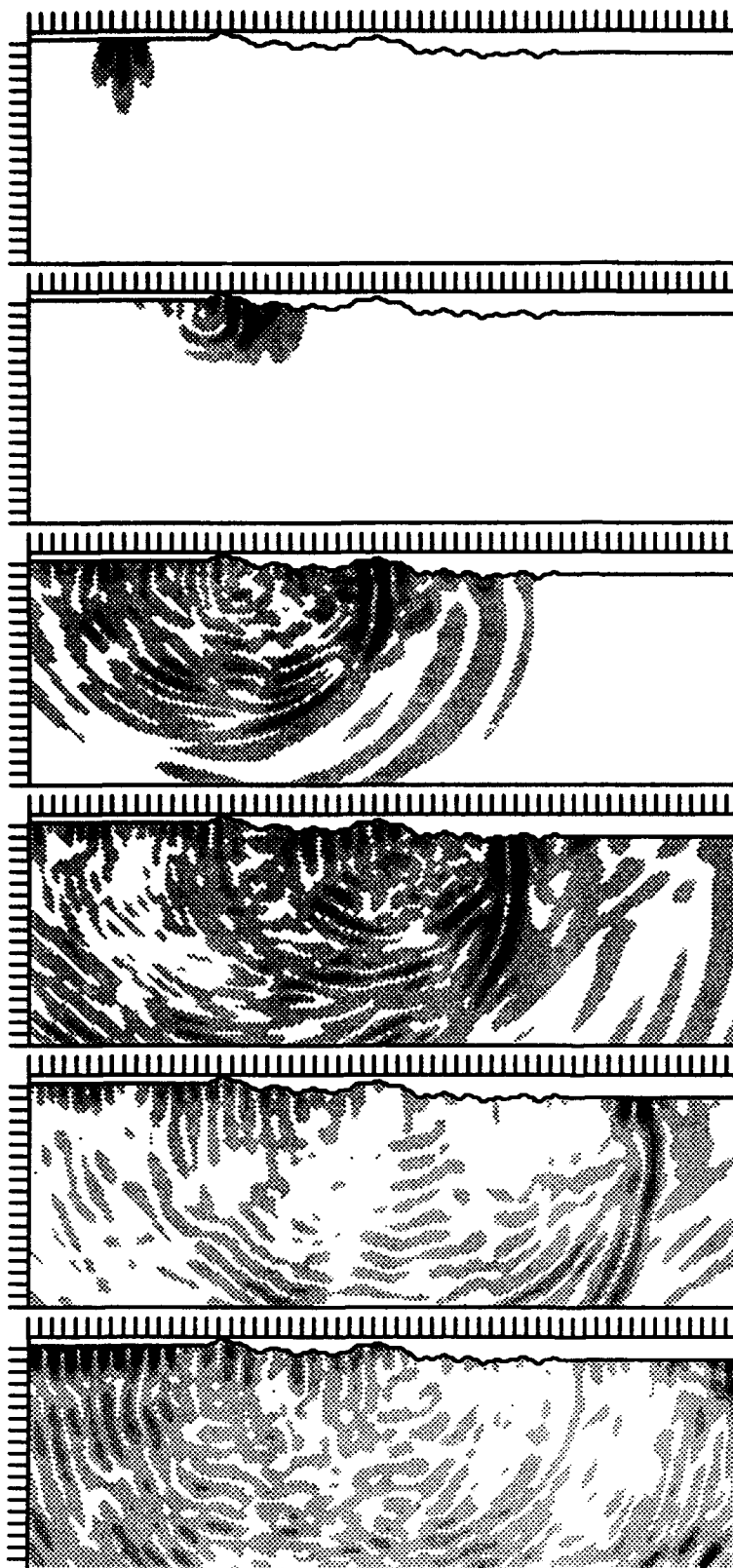
X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit

0.00000E+00 0.75600E-01

Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]

Profile 51 (seed 21691, Pr(1)=0.25)

Figure 27



FD step 0

SQRT(V**2+H**2) .000SEC, 1 600 1 200

X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit

0.00000E+00 0.47898E+00

FD step 400

SQRT(V**2+H**2) 4.000SEC, 1 600 1 200

X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit

0.00000E+00 0.54328E+00

FD step 800

SQRT(V**2+H**2) 8.000SEC, 1 600 1 200

X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit

0.00000E+00 0.24244E+00

FD step 1200

SQRT(V**2+H**2) 12.000SEC, 1 600 1 200

X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit

0.00000E+00 0.17344E+00

FD step 1600

SQRT(V**2+H**2) 16.000SEC, 1 600 1 200

X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit

0.00000E+00 0.20868E+00

FD step 2000

SQRT(V**2+H**2) 20.000SEC, 1 600 1 200

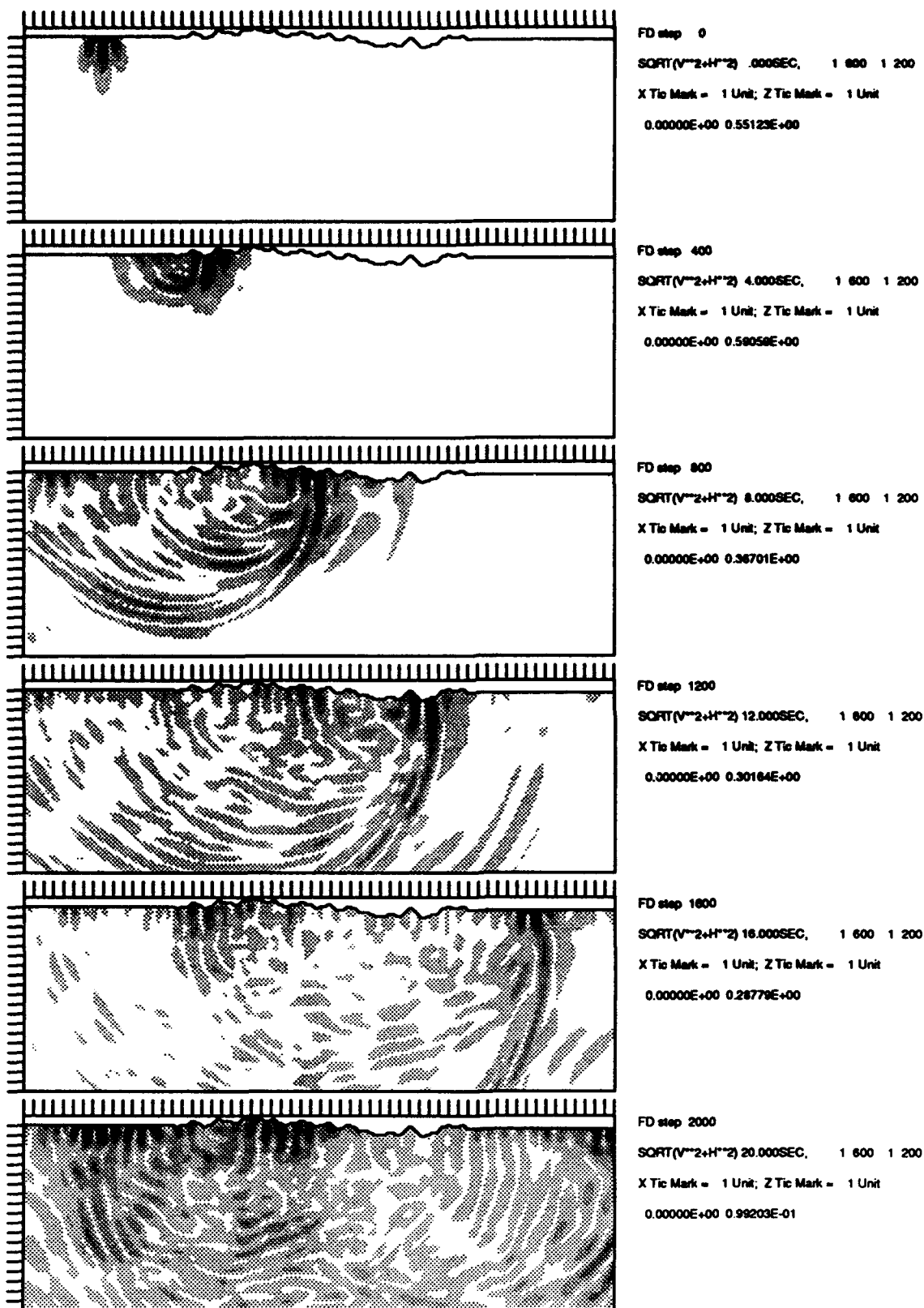
X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit

0.00000E+00 0.67041E-01

Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]

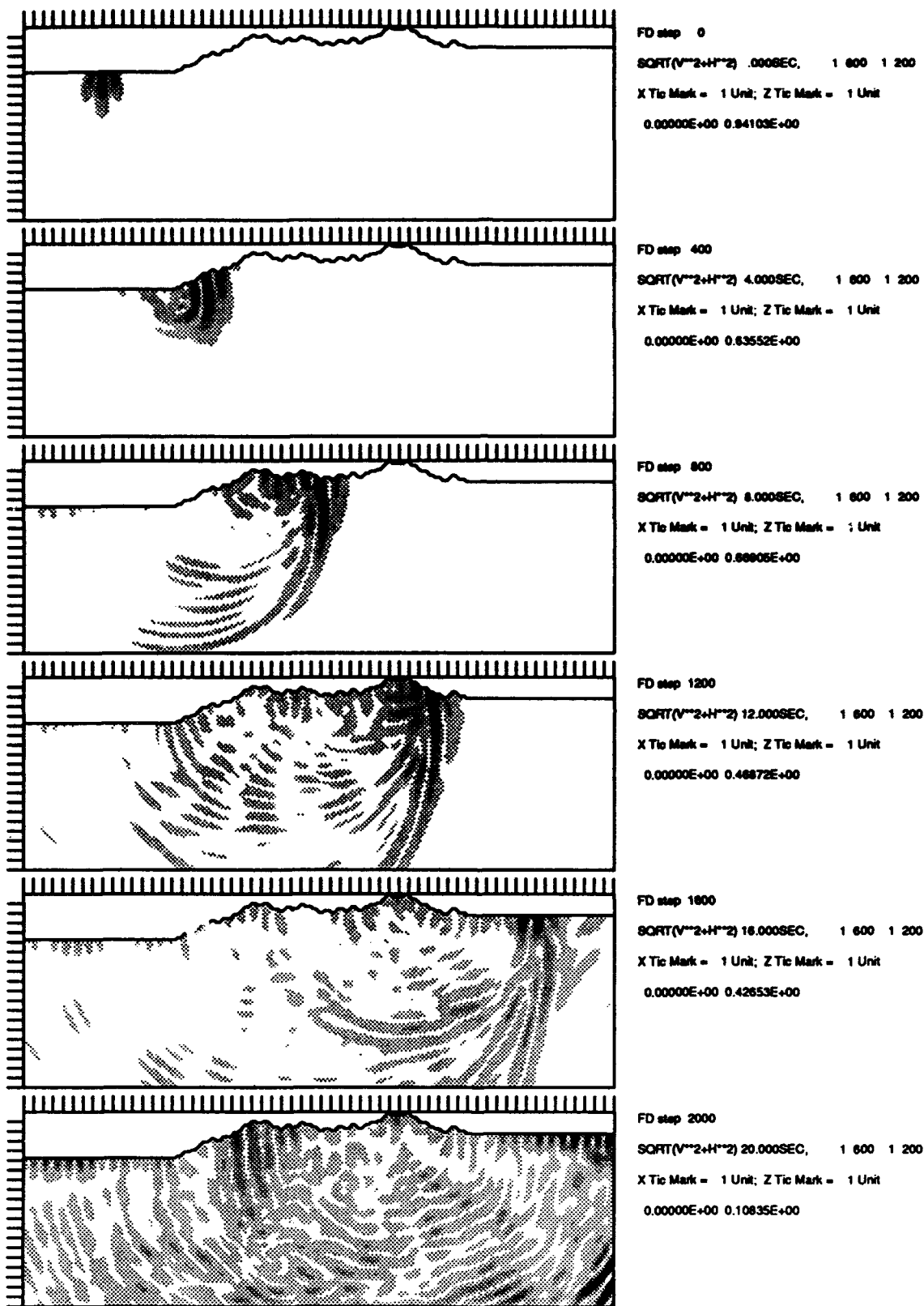
Profile 52 (seed 21696, Pr(1)=0.25)

Figure 28



Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]
 Profile 53 (seed 86037, Pr(1)=0.25)

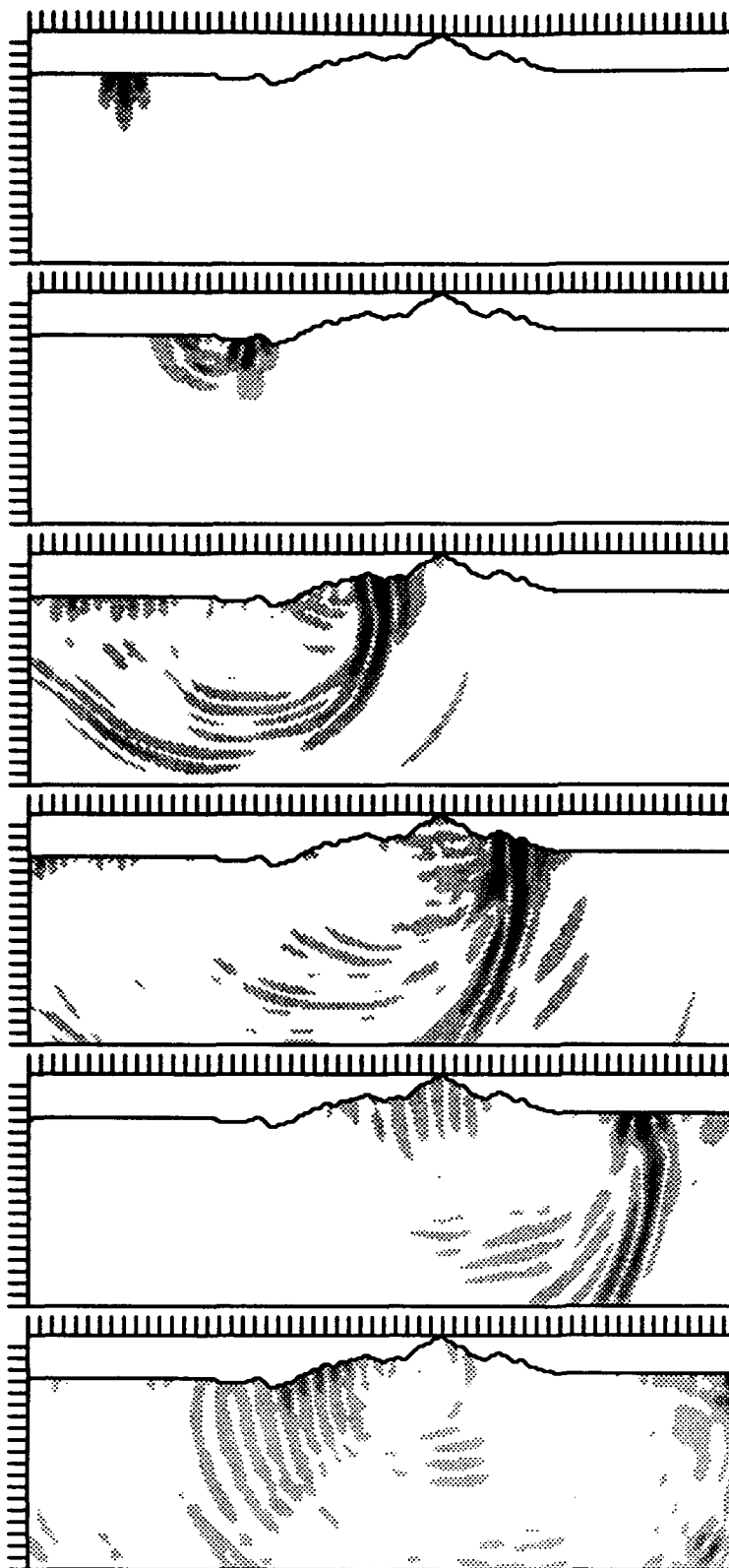
Figure 29



Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]

Profile 61 (seed 93459, Pr(1)=0.30)

Figure 30



FD step 0
 $\text{SQRT}(V^2+H^2)$.000SEC, 1 800 1 200
 X Tie Mark = 1 Unit; Z Tie Mark = 1 Unit
 0.00000E+00 0.94103E+00

FD step 400
 $\text{SQRT}(V^2+H^2)$ 4.000SEC, 1 800 1 200
 X Tie Mark = 1 Unit; Z Tie Mark = 1 Unit
 0.00000E+00 0.80212E+00

FD step 800
 $\text{SQRT}(V^2+H^2)$ 8.000SEC, 1 800 1 200
 X Tie Mark = 1 Unit; Z Tie Mark = 1 Unit
 0.00000E+00 0.44658E+00

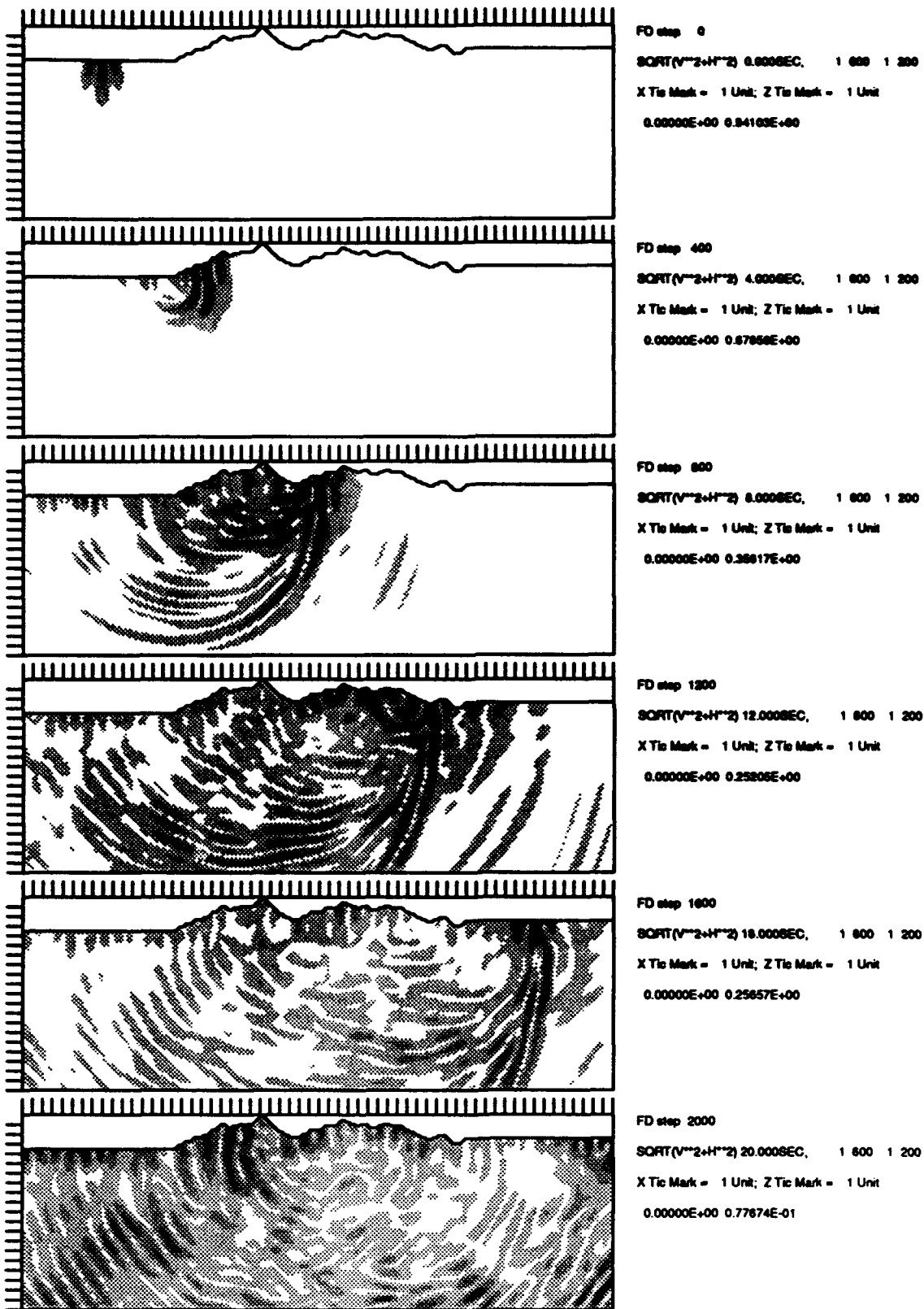
FD step 1200
 $\text{SQRT}(V^2+H^2)$ 12.000SEC, 1 800 1 200
 X Tie Mark = 1 Unit; Z Tie Mark = 1 Unit
 0.00000E+00 0.30517E+00

FD step 1600
 $\text{SQRT}(V^2+H^2)$ 16.000SEC, 1 800 1 200
 X Tie Mark = 1 Unit; Z Tie Mark = 1 Unit
 0.00000E+00 0.31779E+00

FD step 2000
 $\text{SQRT}(V^2+H^2)$ 20.000SEC, 1 800 1 200
 X Tie Mark = 1 Unit; Z Tie Mark = 1 Unit
 0.00000E+00 0.12330E+00

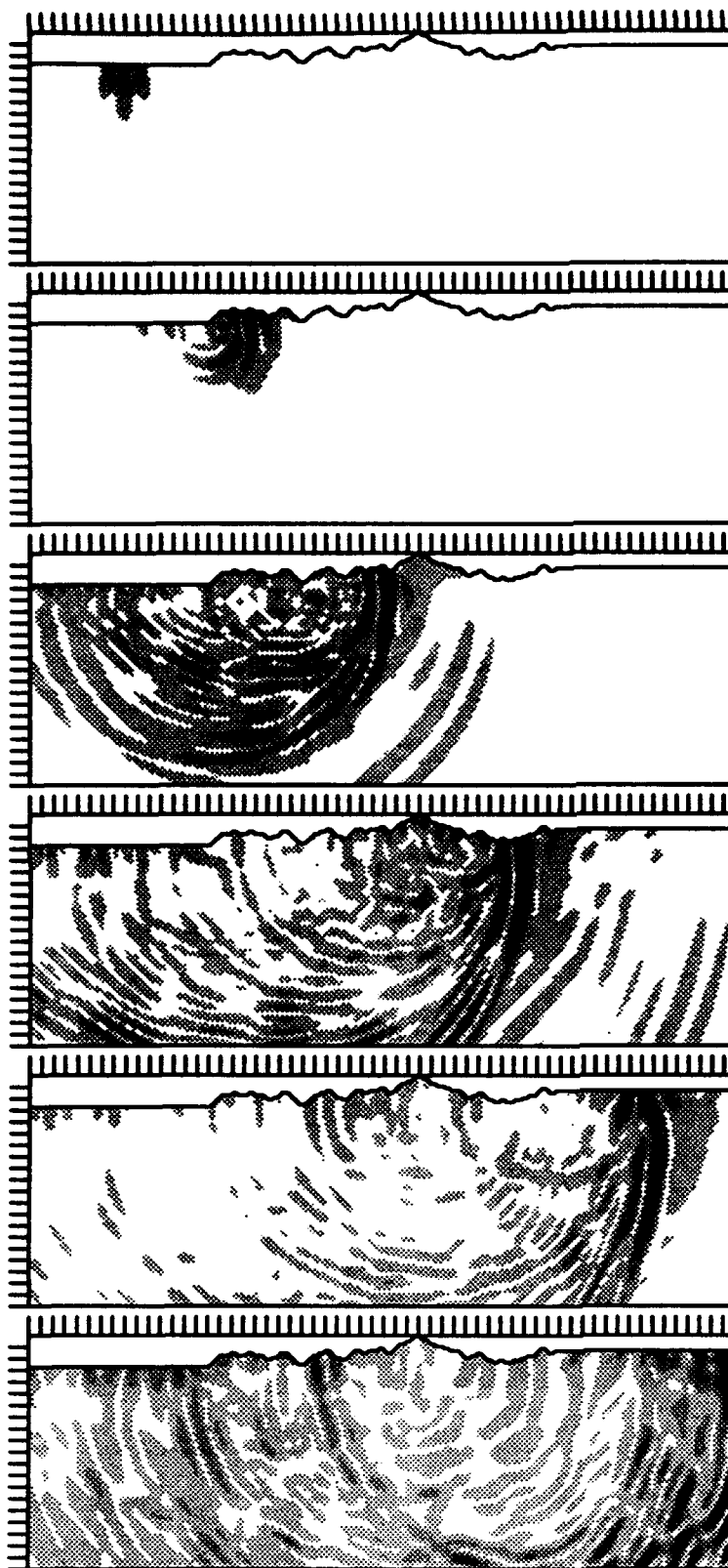
Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]
 Profile 62 (seed 93468, Pr(1)=0.30)

Figure 31



Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]
 Profile 63 (seed 93479, Pr(1)=0.30)

Figure 32



FD step 0
 $\text{SQRT}(V^2+H^2)$.000SEC, 1 600 1 200
 X Tio Mark = 1 Unit; Z Tio Mark = 1 Unit
 0.00000E+00 0.84103E+00

FD step 400
 $\text{SQRT}(V^2+H^2)$ 4.000SEC, 1 600 1 200
 X Tio Mark = 1 Unit; Z Tio Mark = 1 Unit
 0.00000E+00 0.72482E+00

FD step 800
 $\text{SQRT}(V^2+H^2)$ 8.000SEC, 1 600 1 200
 X Tio Mark = 1 Unit; Z Tio Mark = 1 Unit
 0.00000E+00 0.31836E+00

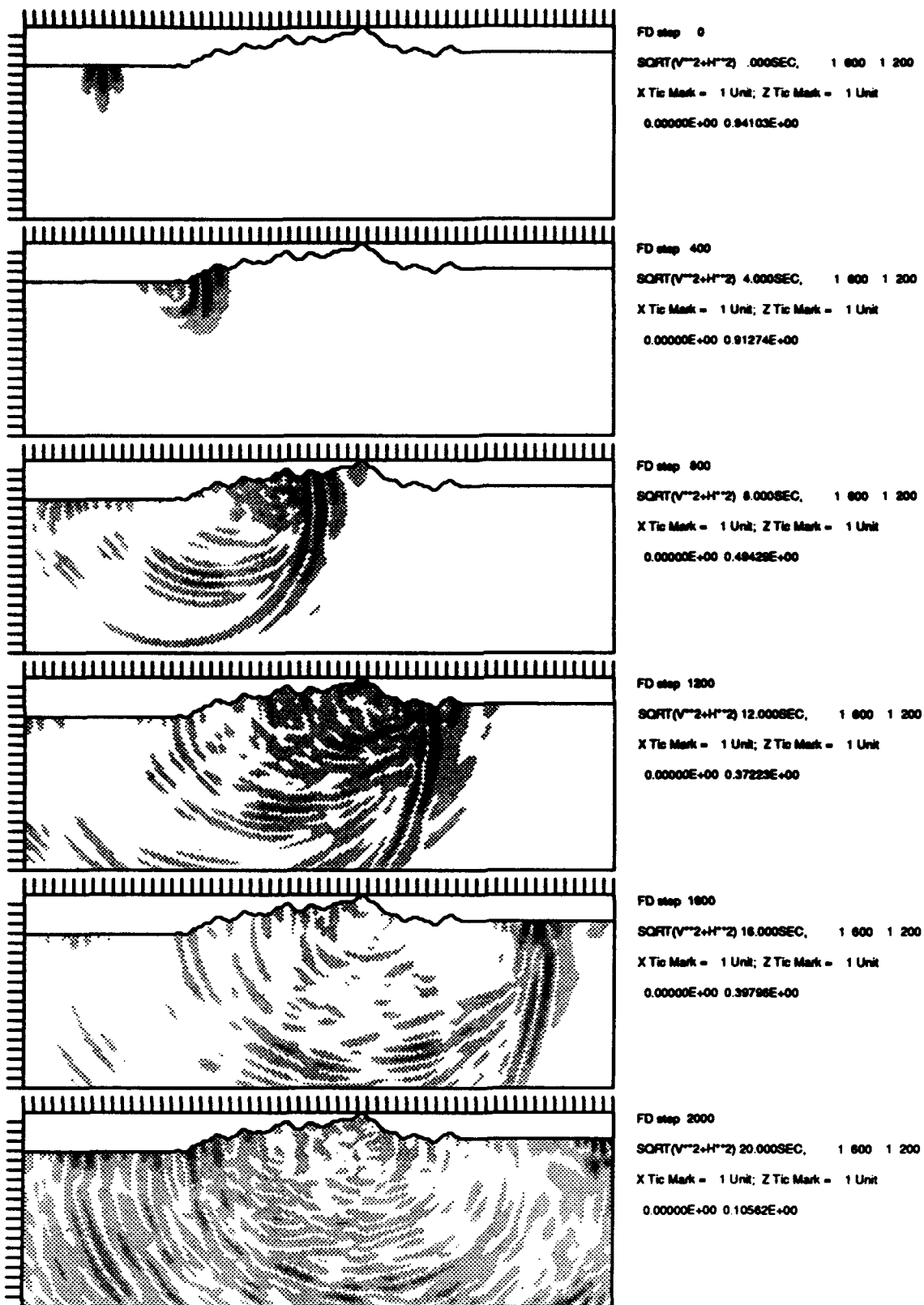
FD step 1200
 $\text{SQRT}(V^2+H^2)$ 12.000SEC, 1 600 1 200
 X Tio Mark = 1 Unit; Z Tio Mark = 1 Unit
 0.00000E+00 0.20201E+00

FD step 1600
 $\text{SQRT}(V^2+H^2)$ 16.000SEC, 1 600 1 200
 X Tio Mark = 1 Unit; Z Tio Mark = 1 Unit
 0.00000E+00 0.20557E+00

FD step 2000
 $\text{SQRT}(V^2+H^2)$ 20.000SEC, 1 600 1 200
 X Tio Mark = 1 Unit; Z Tio Mark = 1 Unit
 0.00000E+00 0.51740E-01

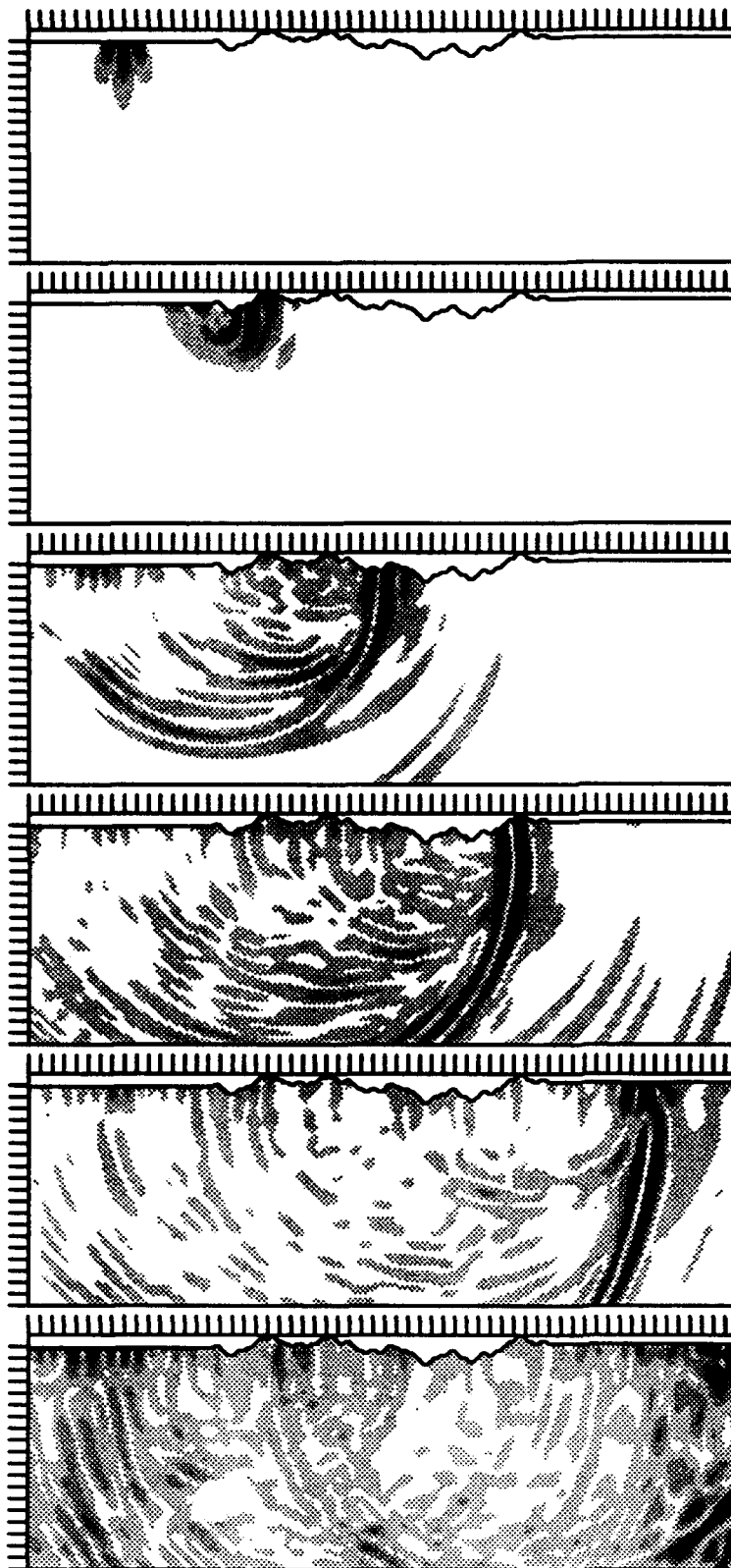
Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]
 Profile 64 (seed 55473, Pr(1)=0.32)

Figure 33



Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]
 Profile 65 (seed 55499, Pr(1)=0.32)

Figure 34



FD step 0
 $\text{SQRT}(V^2+H^2)$ 0.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.63158E+00

FD step 400
 $\text{SQRT}(V^2+H^2)$ 4.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.50801E+00

FD step 800
 $\text{SQRT}(V^2+H^2)$ 8.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.31194E+00

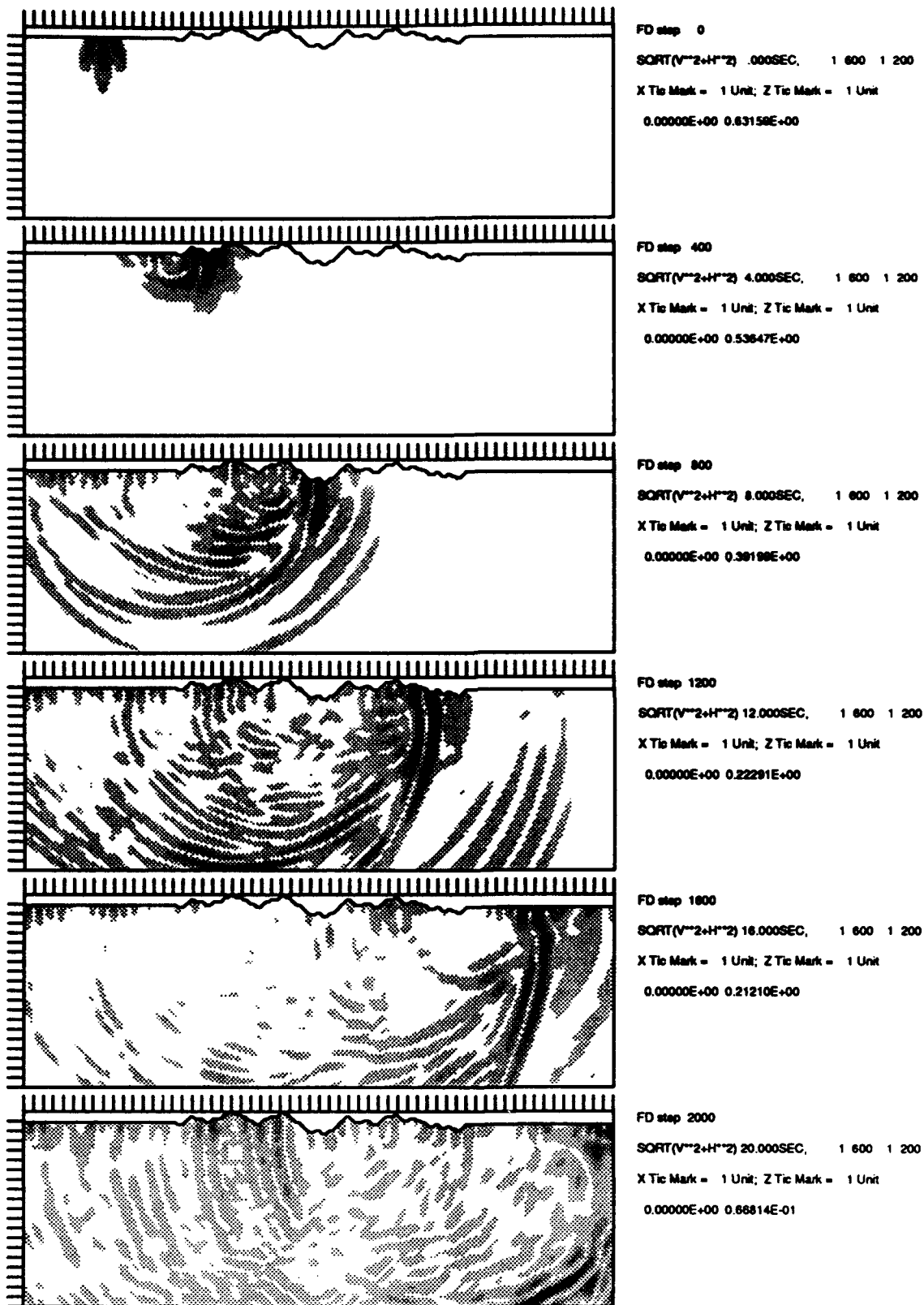
FD step 1200
 $\text{SQRT}(V^2+H^2)$ 12.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.17408E+00

FD step 1600
 $\text{SQRT}(V^2+H^2)$ 16.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.13553E+00

FD step 2000
 $\text{SQRT}(V^2+H^2)$ 20.000SEC, 1 600 1 200
 X Tic Mark = 1 Unit; Z Tic Mark = 1 Unit
 0.00000E+00 0.36528E-01

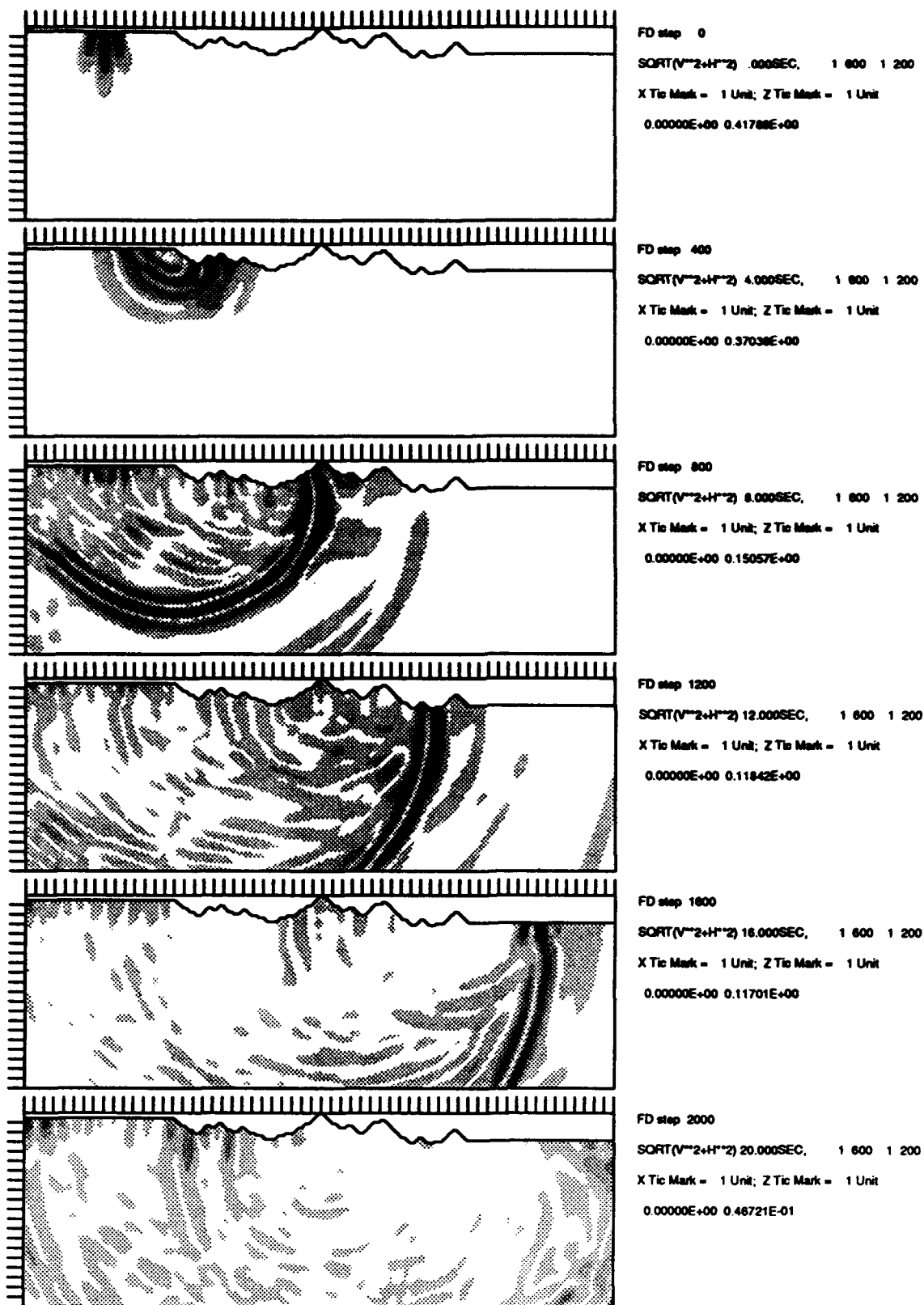
Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]
 Profile 66 (seed 55446, Pr(1)=0.32)

Figure 35



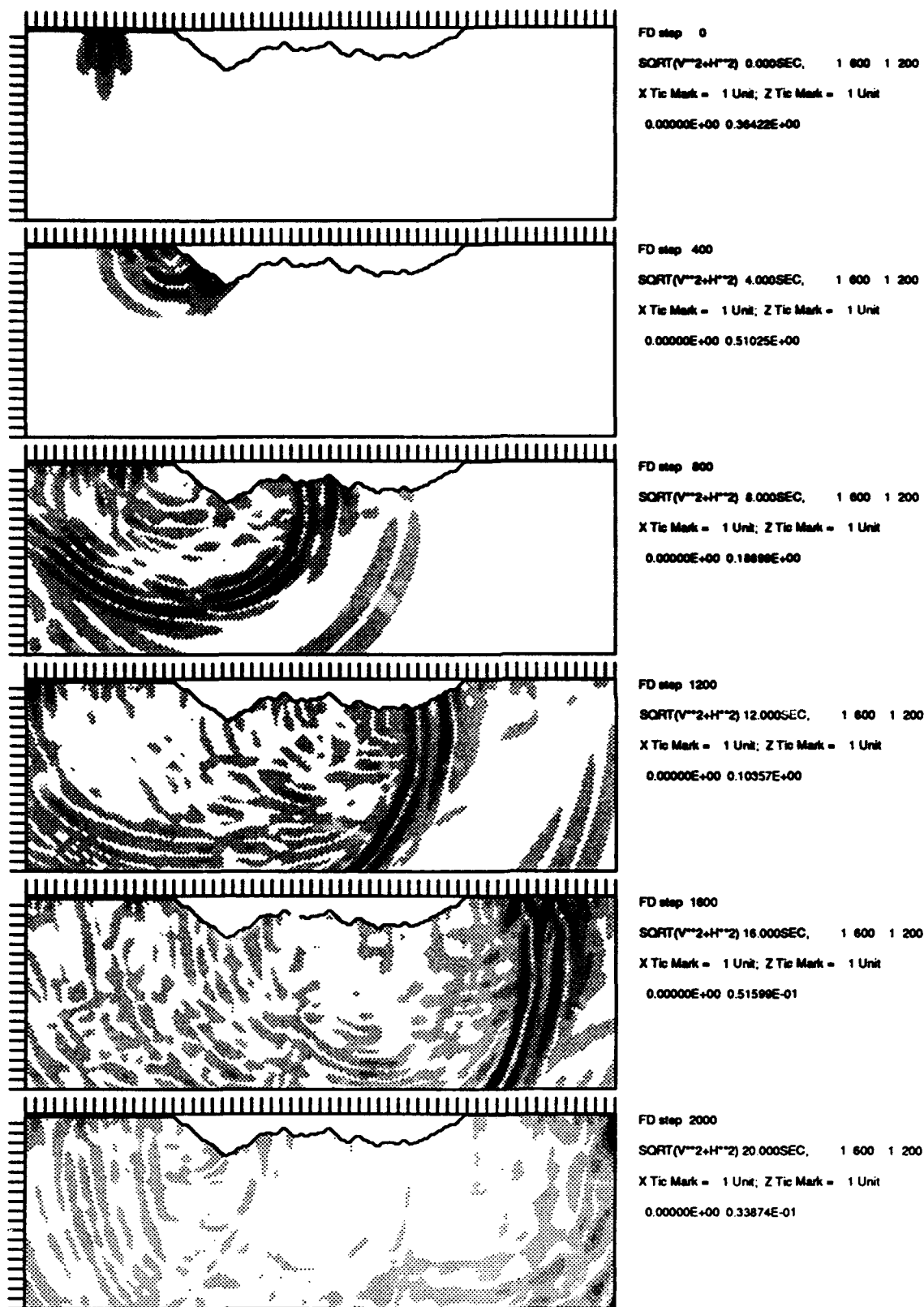
Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]
 Profile 71 (seed 22192, Pr(1)=0.35)

Figure 36



Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]
 Profile 72 (seed 31087, Pr(1)=0.35)

Figure 37



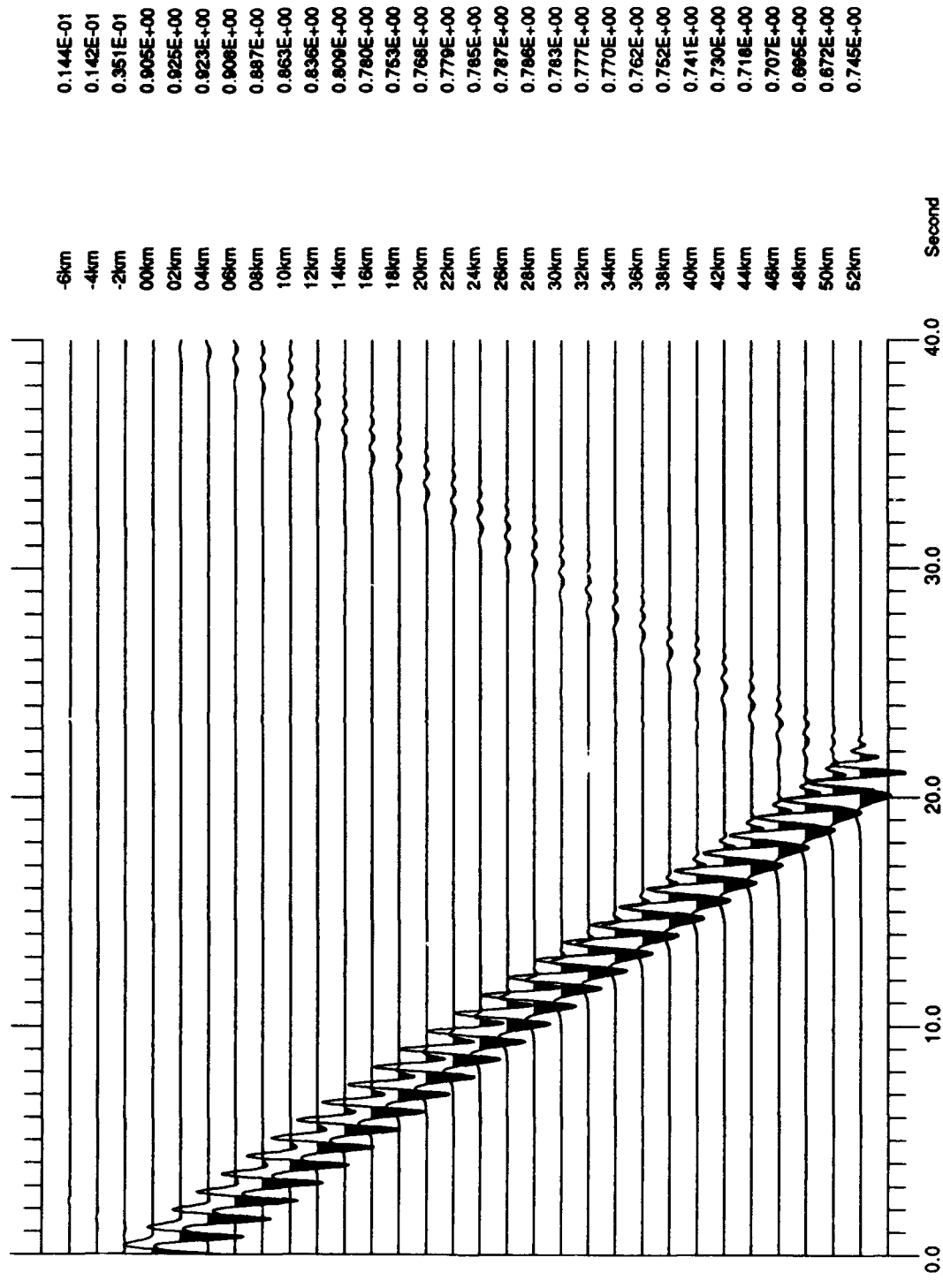
Rg (1Hz:2.665km); Grid 600*500 [dx=0.1km,dt=10ms]
 Profile 73 (seed 86061, Pr(1)=0.35)

Figure 38

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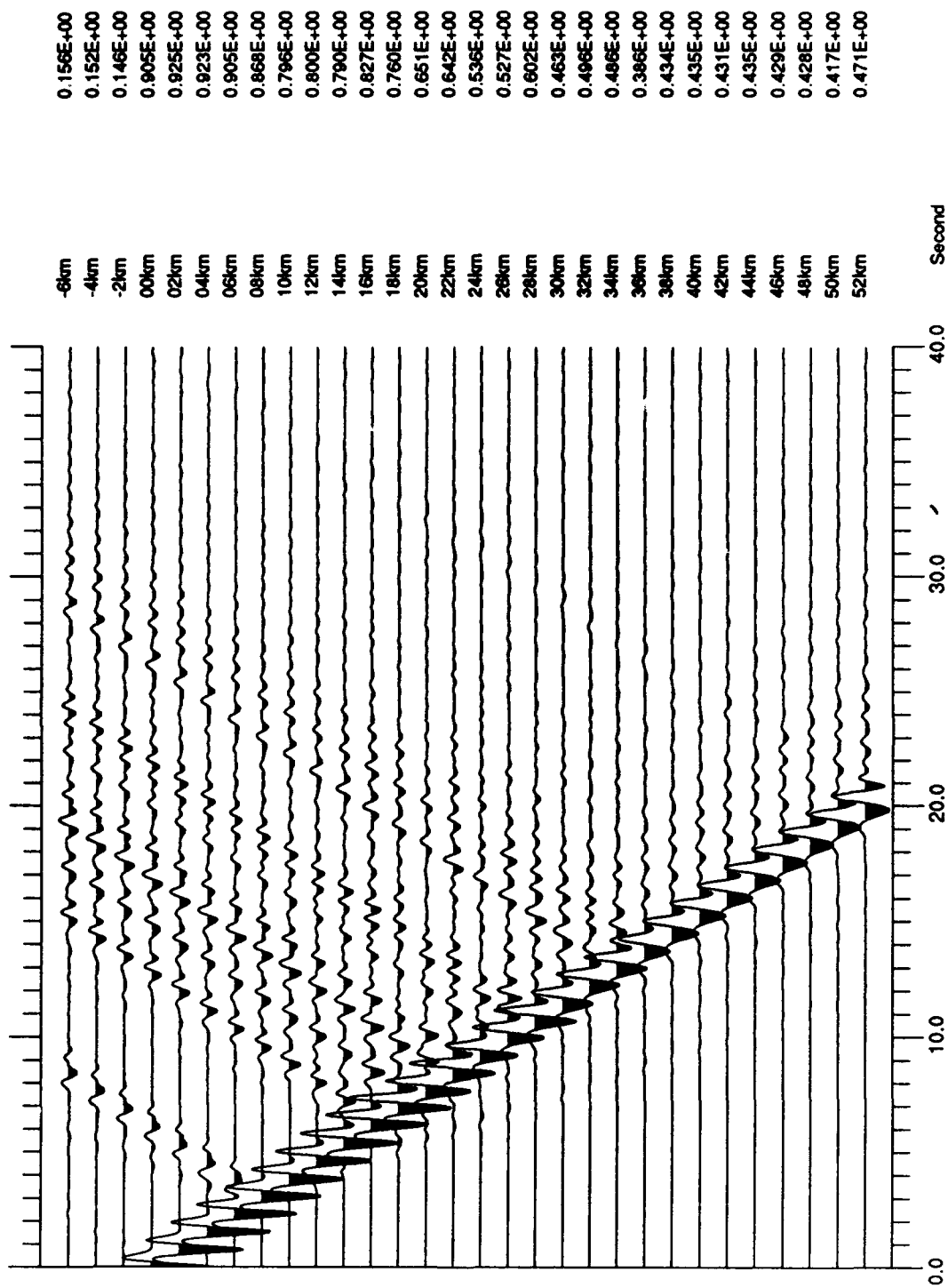
..



Profile 00(seed 00, Pr(1)=00), Surface Sensors

VERT, same scale, decimated by 4

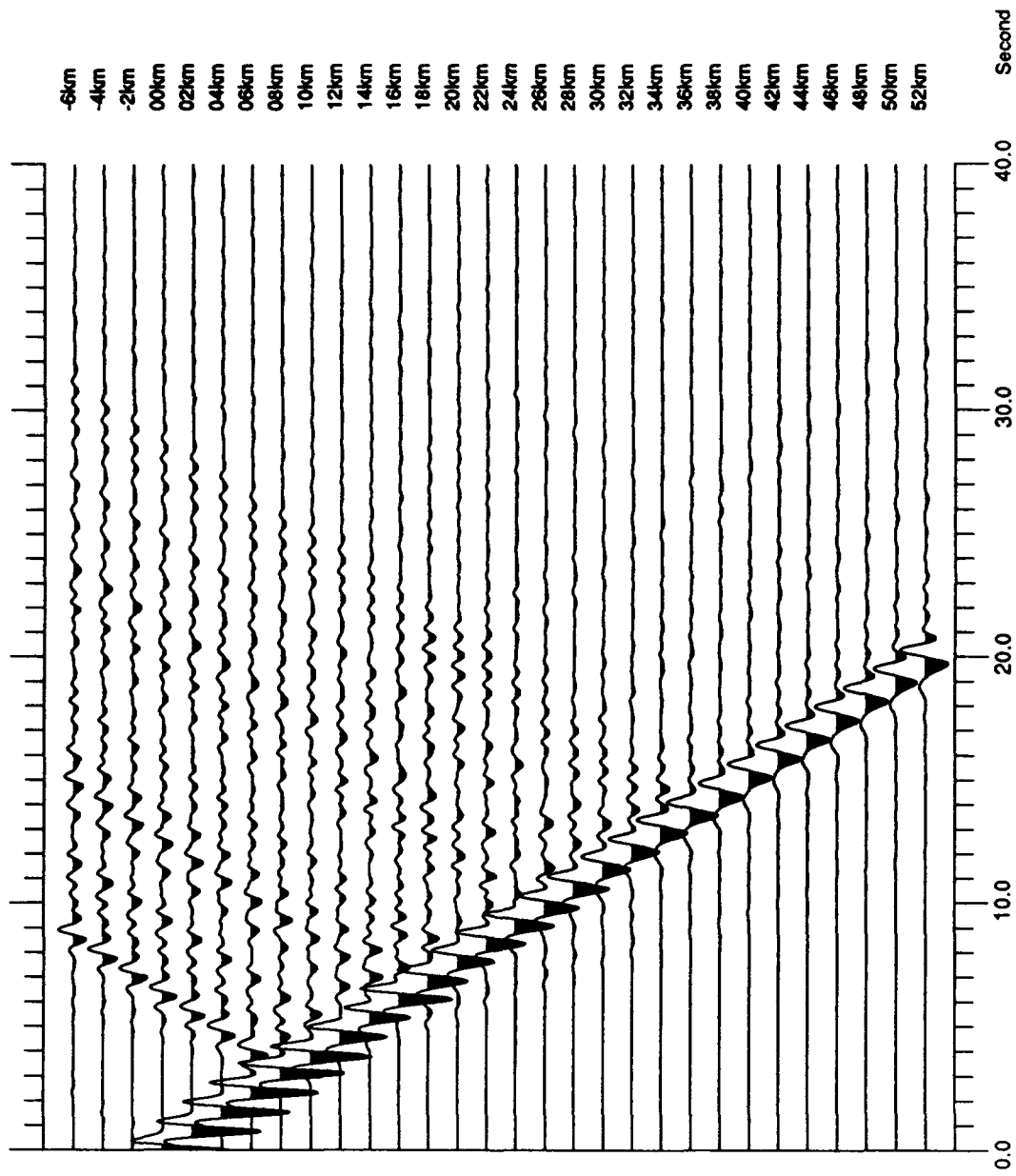
Figure 39



Profile 11 (seed 22887, $Pr(1)=0.05$), Surface Sensors

VERT, same scale, decimated by 5

1 1
 1 2
 1 3
 1 4
 1 5
 1 6
 1 7
 1 8
 1 9
 1 10
 1 11
 1 12
 1 13
 1 14
 1 15
 1 16
 1 17
 1 18
 1 19
 1 20
 1 21
 1 22
 1 23
 1 24
 1 25
 1 26
 1 27
 1 28
 1 29
 1 30

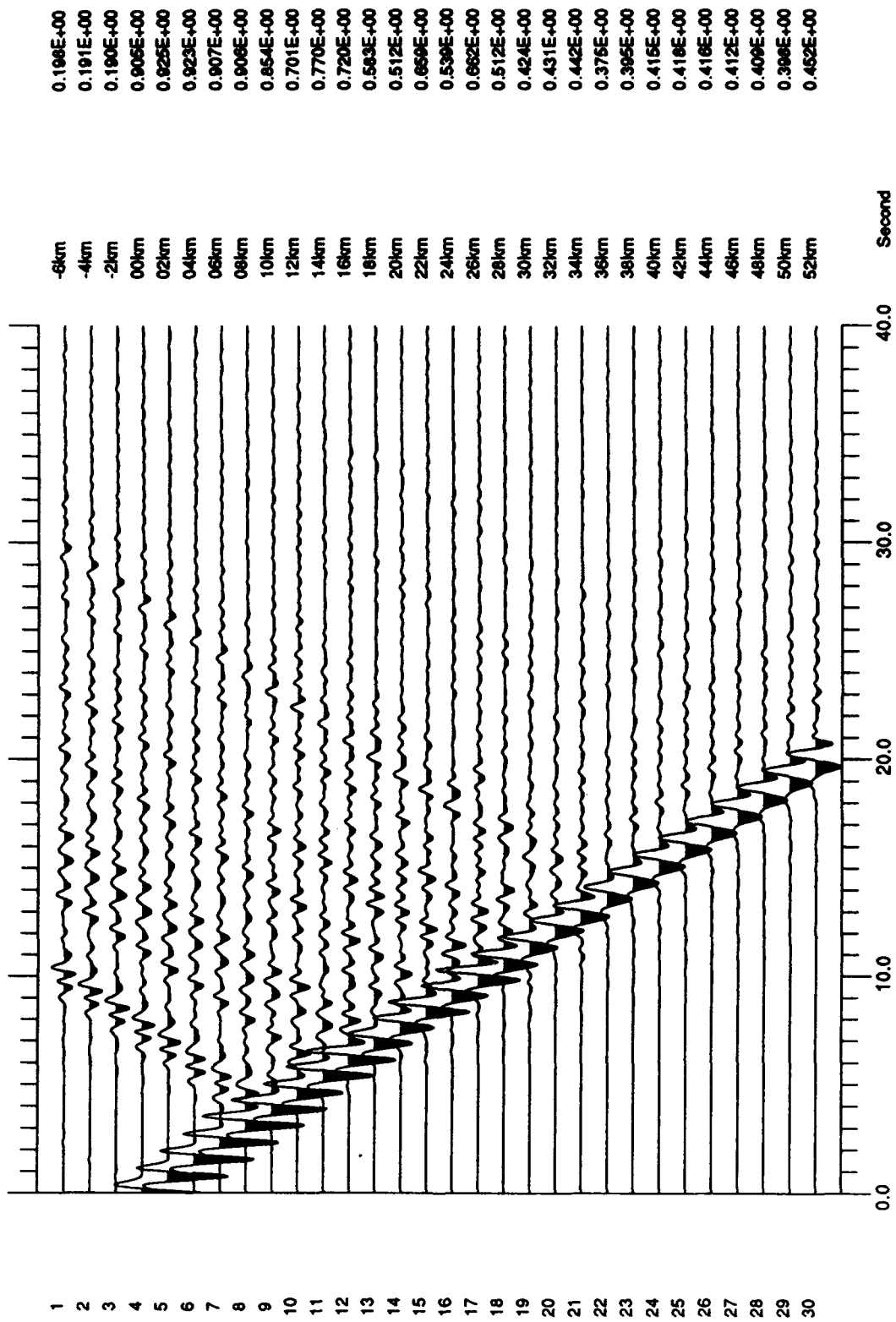


0.208E+00
 0.209E+00
 0.189E+00
 0.905E+00
 0.925E+00
 0.923E+00
 0.907E+00
 0.856E+00
 0.827E+00
 0.631E+00
 0.554E+00
 0.728E+00
 0.537E+00
 0.501E+00
 0.532E+00
 0.528E+00
 0.470E+00
 0.484E+00
 0.376E+00
 0.370E+00
 0.355E+00
 0.369E+00
 0.320E+00
 0.306E+00
 0.307E+00
 0.310E+00
 0.308E+00
 0.311E+00
 0.304E+00
 0.351E+00

Profile 14(seed 91333, Pr(1)=0.07), Surface Sensors

VERT, same scale, decimated by 5

Figure 43

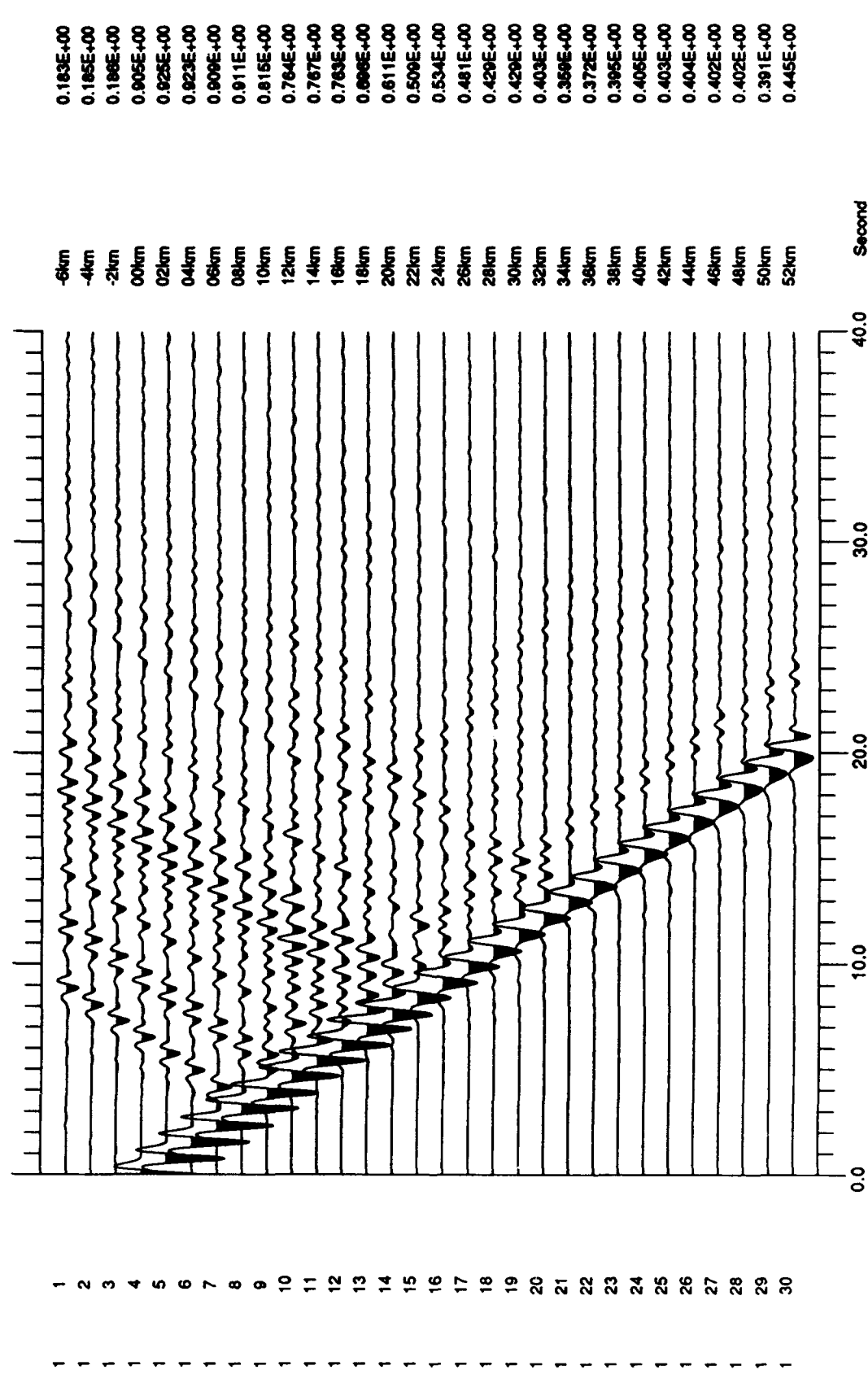


Profile 15(seed 91350, Pr(1)=0.07), Surface Sensors

VERT, same scale, decimated by 5

Figure 44

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Profile 16(seed 91285, Pr(1)=0.07), Surface Sensors

VERT, same scale, decimated by 5

Figure 45

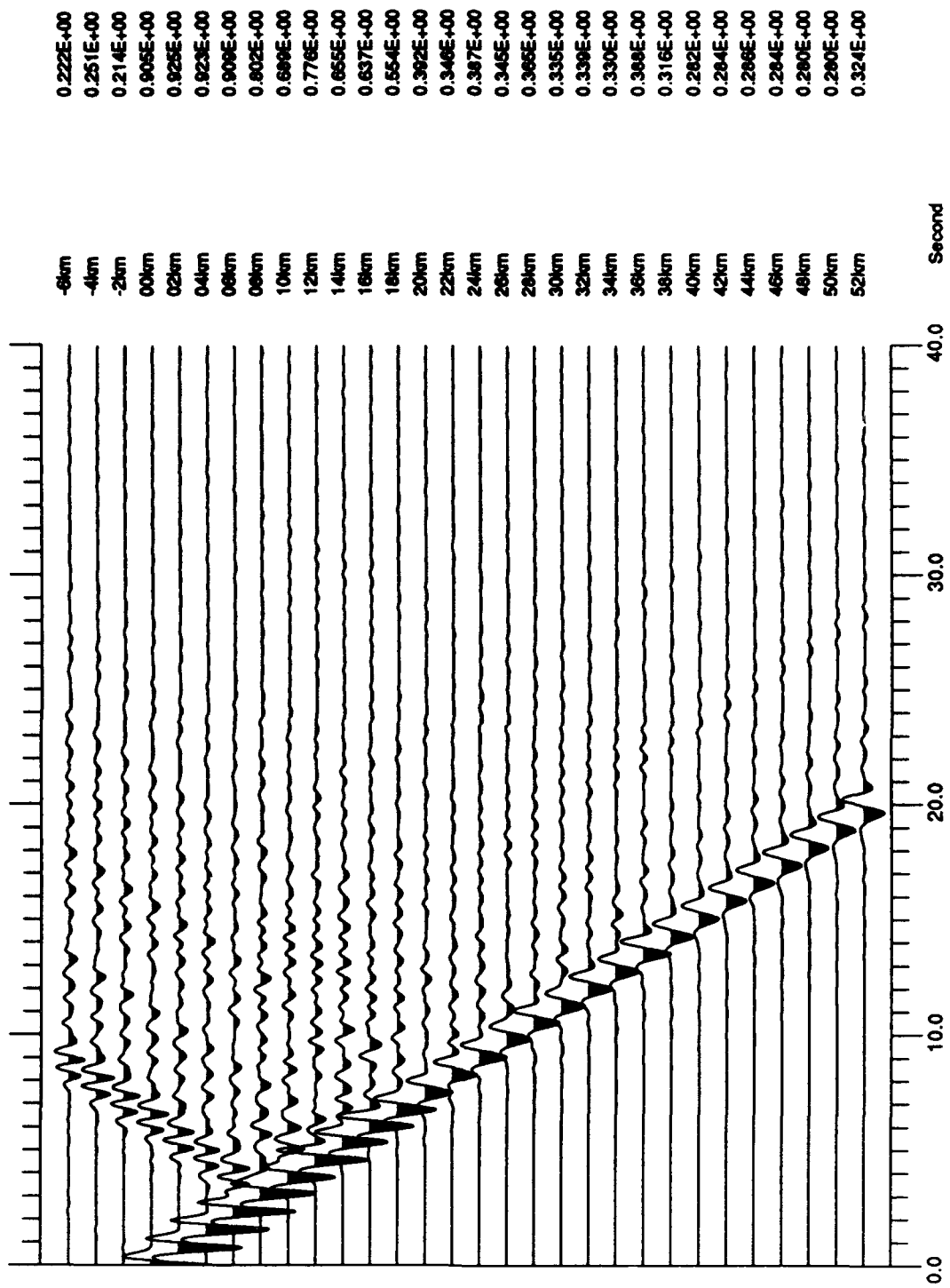
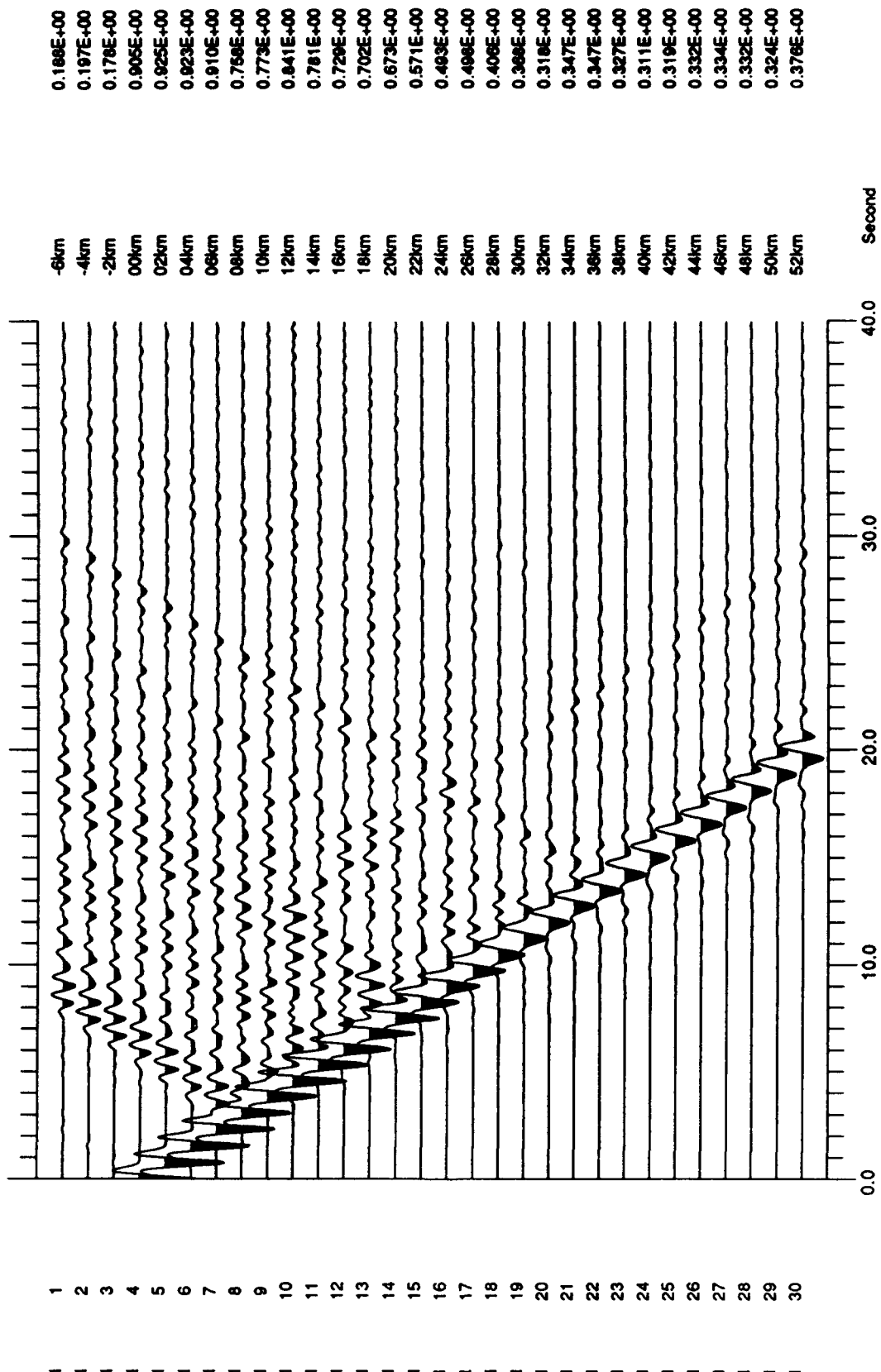


Figure 46

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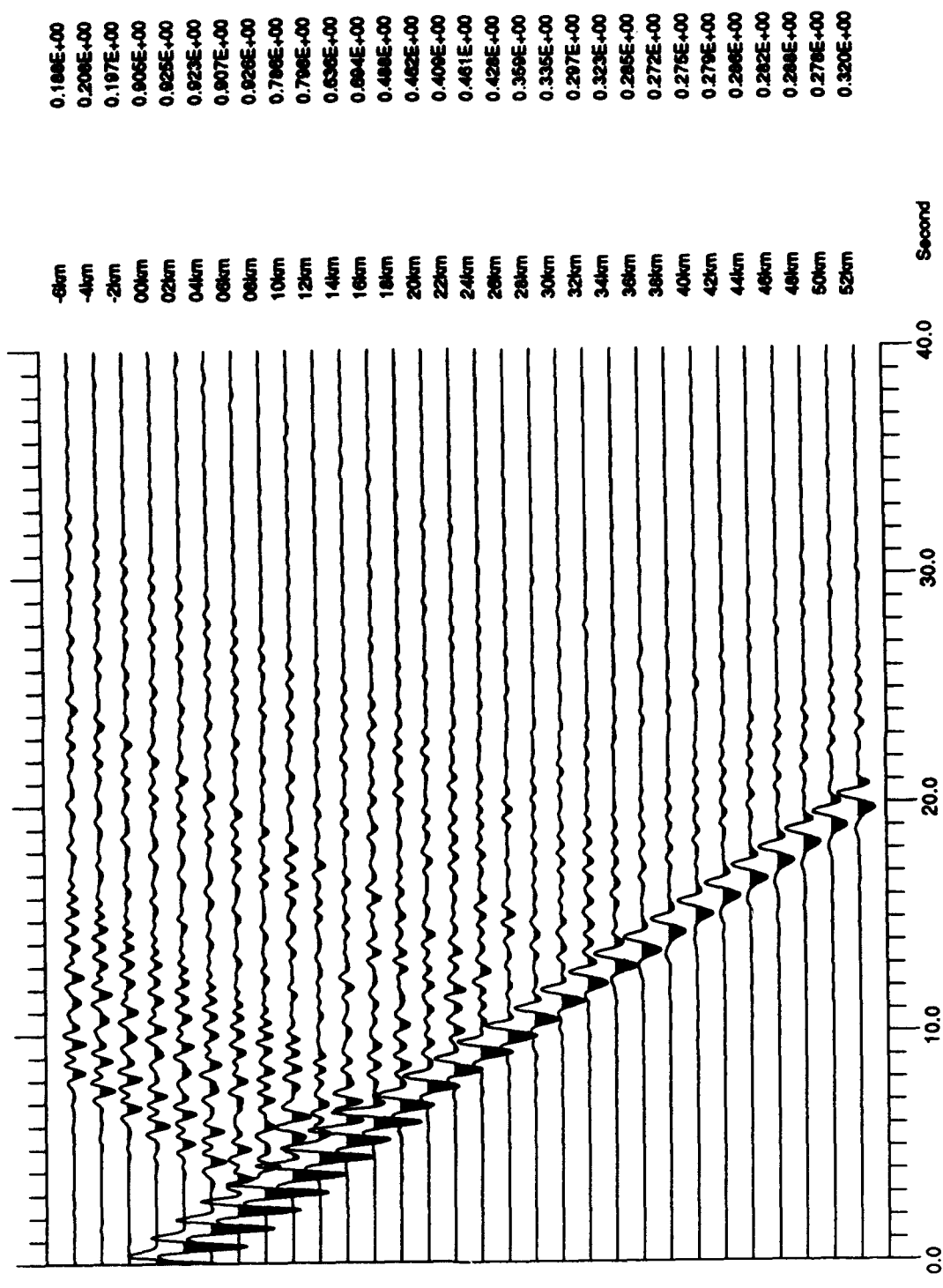
..



Profile 22(seed 93347, Pr(1)=0.10), Surface Sensors

VERT, same scale, decimated by 5

Figure 47



Profile 23(seed 93356, Pr(1)=0.10), Surface Sensors

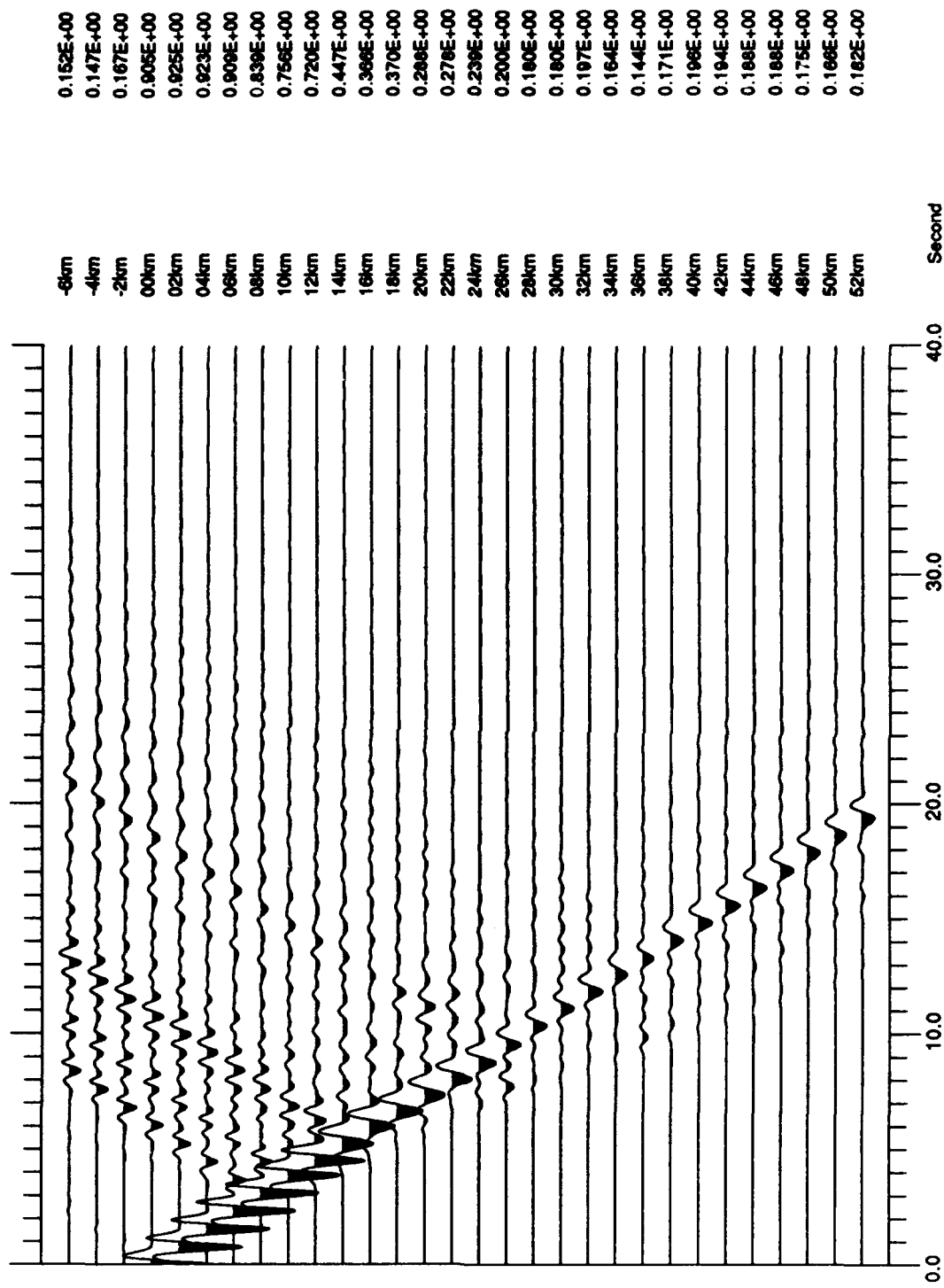
VERT. same scale, decimated by 5

Figure 48

.. ..

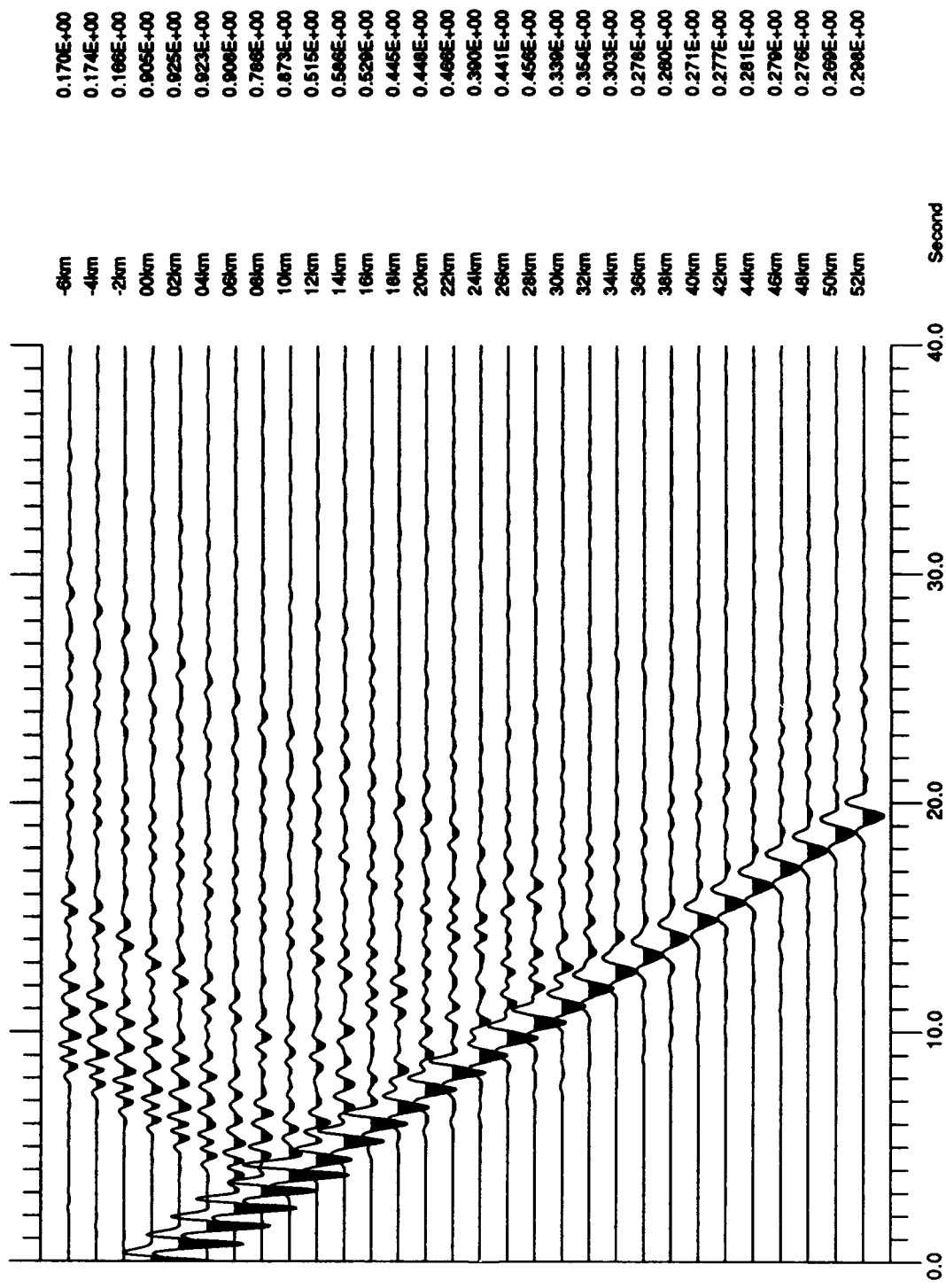
.. ..

.. ..



Profile 31(seed 748546615, Pr(1)=0.15), Surface Sensors

VERT, same scale, decimated by 5

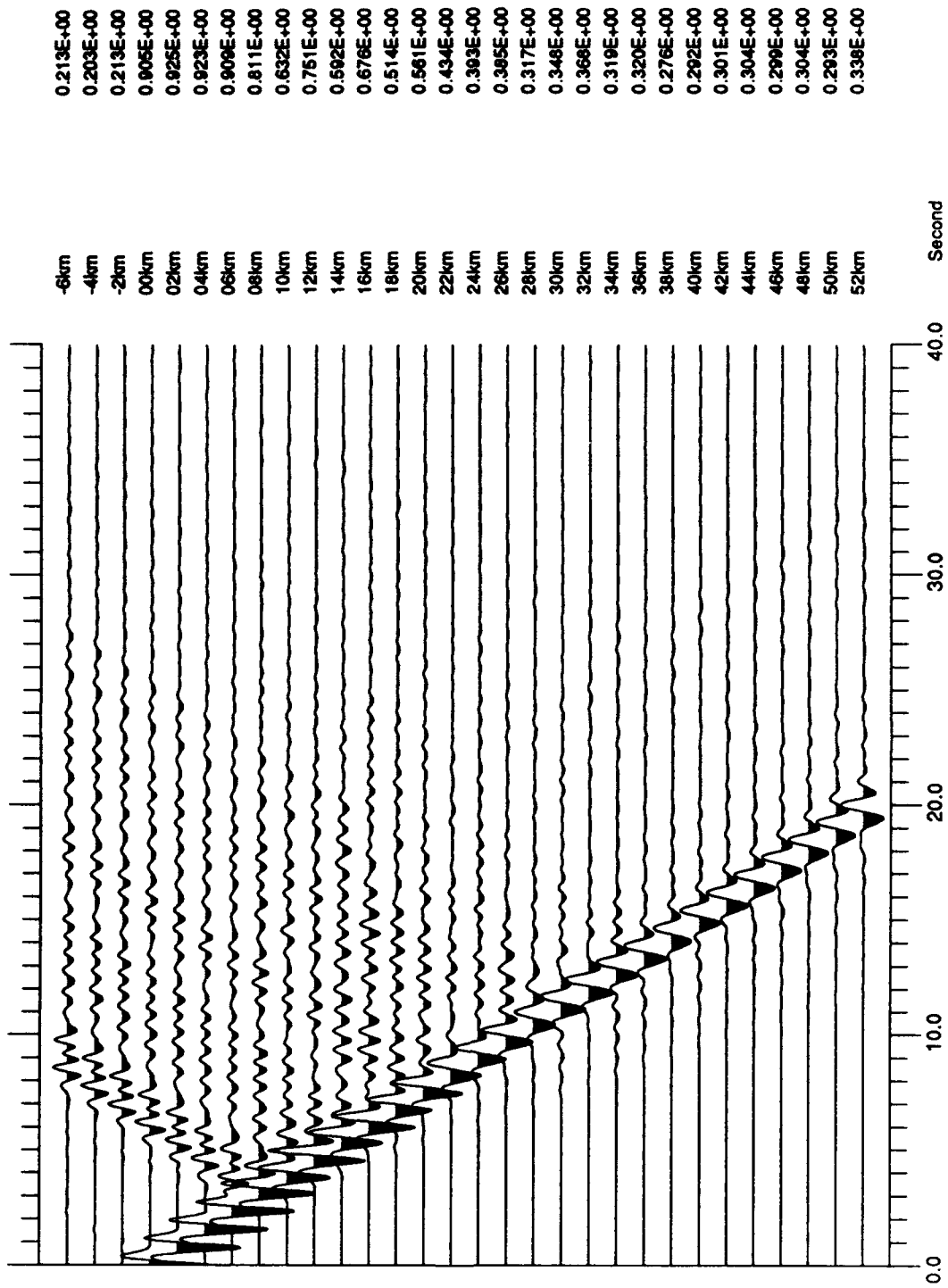


Profile 32(seed 20333, Pr(1)=0.15), Surface Sensors

VERT, same scale, decimated by 5

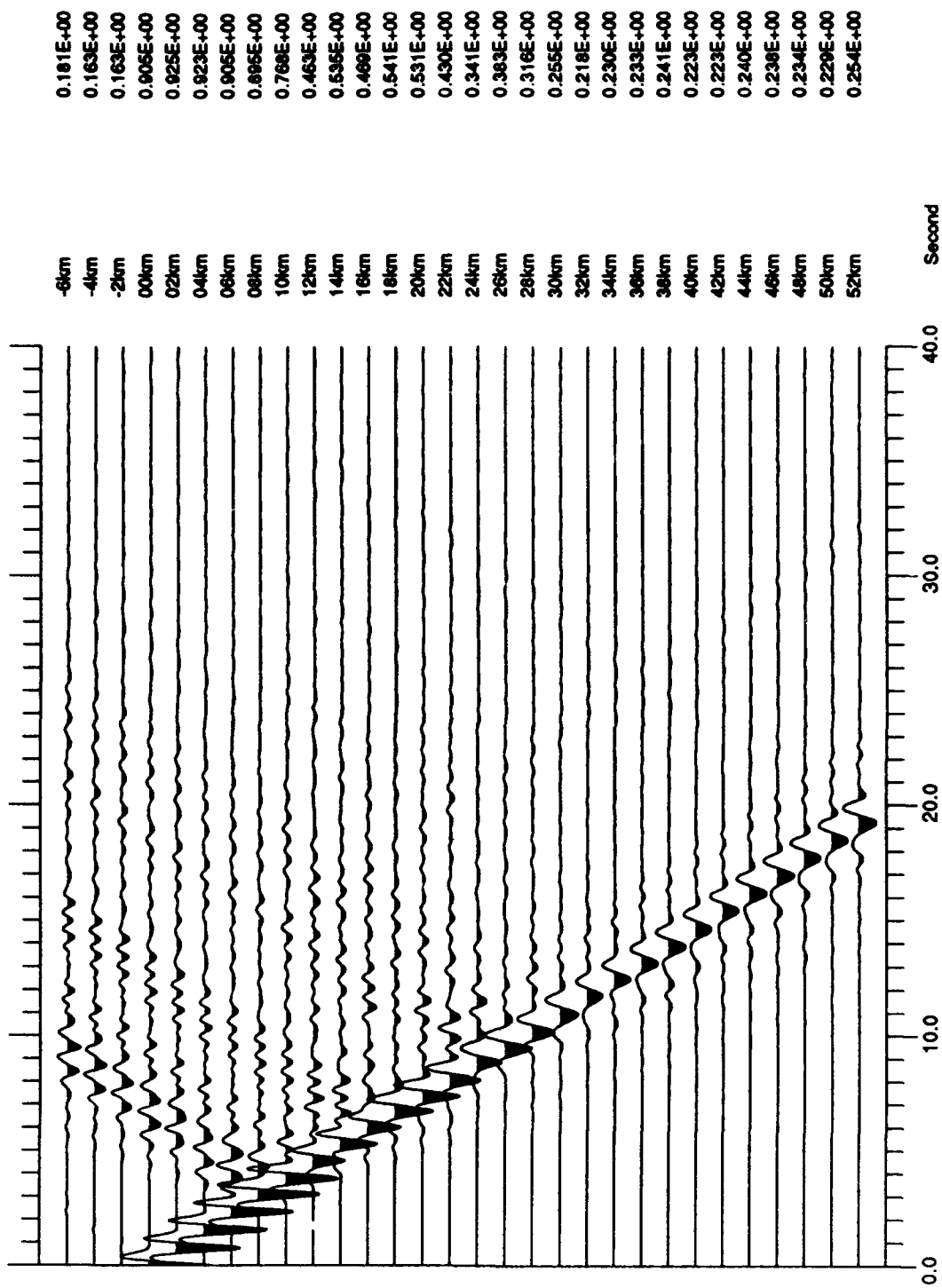
Figure 50

1 1
2 1
3 1
4 1
5 1
6 1
7 1
8 1
9 1
10 1
11 1
12 1
13 1
14 1
15 1
16 1
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20 1
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22 1
23 1
24 1
25 1
26 1
27 1
28 1
29 1
30 1



Profile 33(seed 86016, Pr(1)=0.15), Surface Sensors

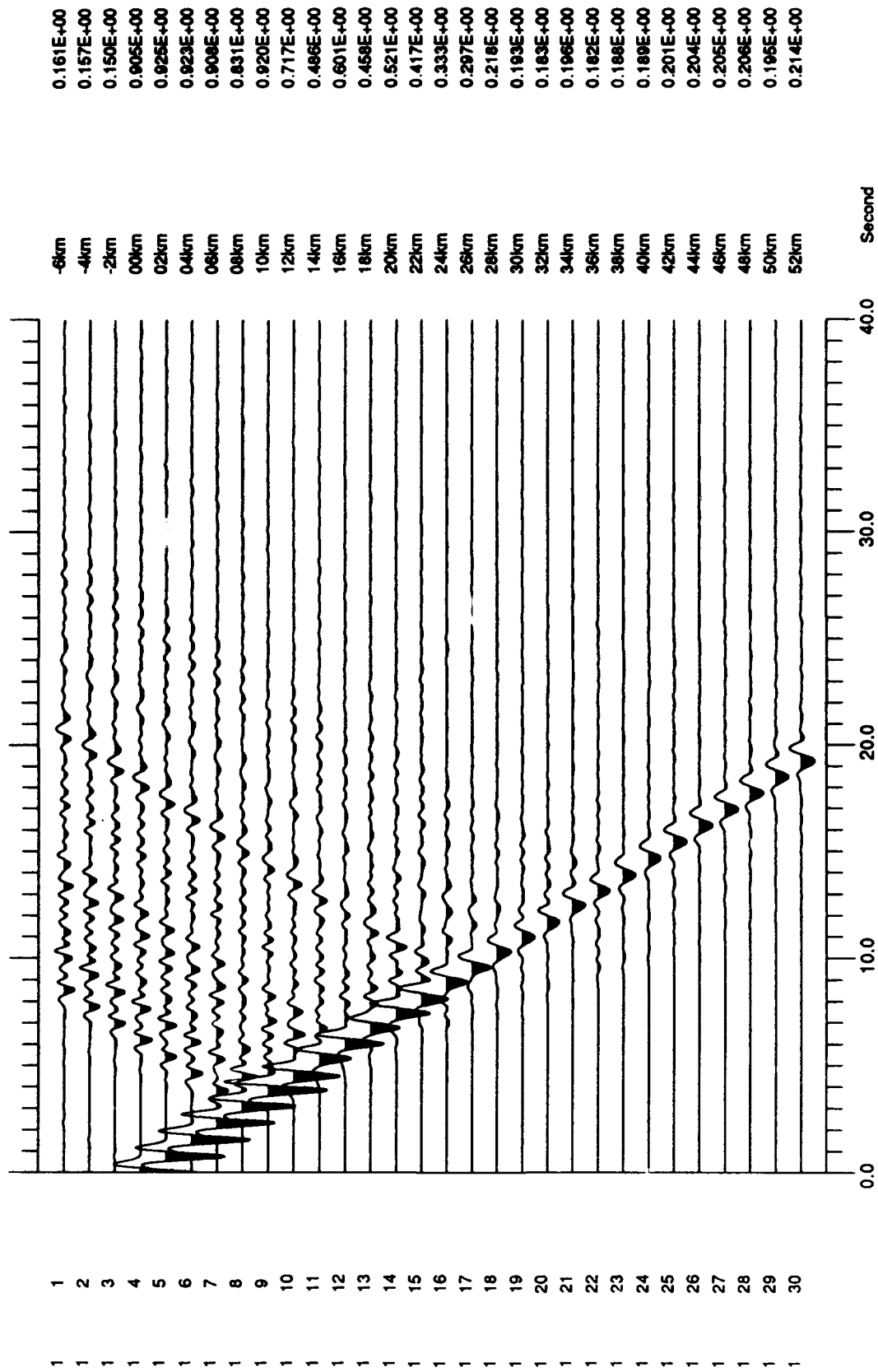
VERT, same scale, decimated by 5



Profile 41(seed 93397, Pr(1)=0.20), Surface Sensors

VERT, same scale, decimated by 5

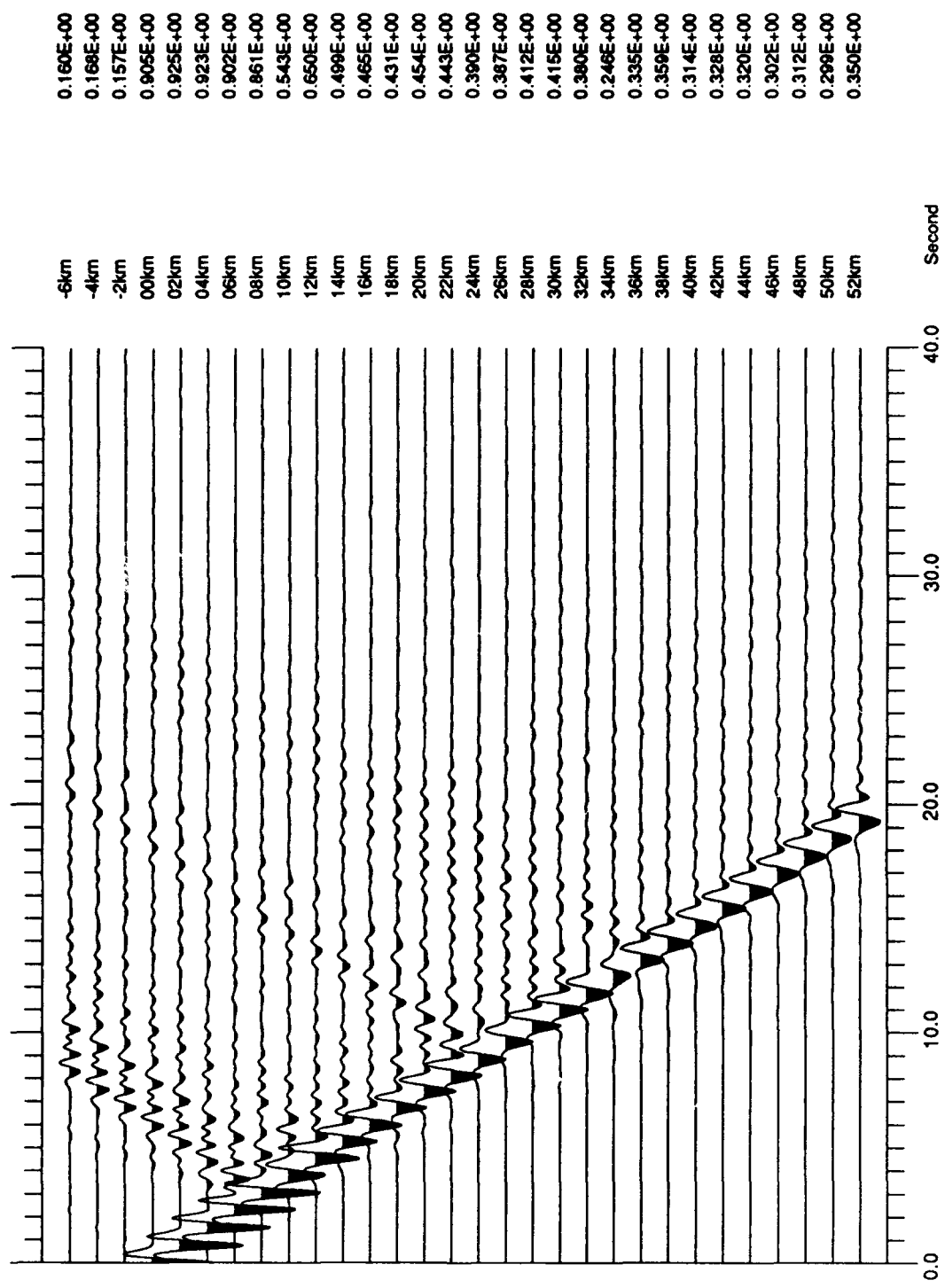
Figure 52



Profile 42(seed 93407, Pr(1)=0.20), Surface Sensors

VERT, same scale, decimated by 5

Figure 53



Profile 43(seed 12345, Pr(1)=0.20), Surface Sensors

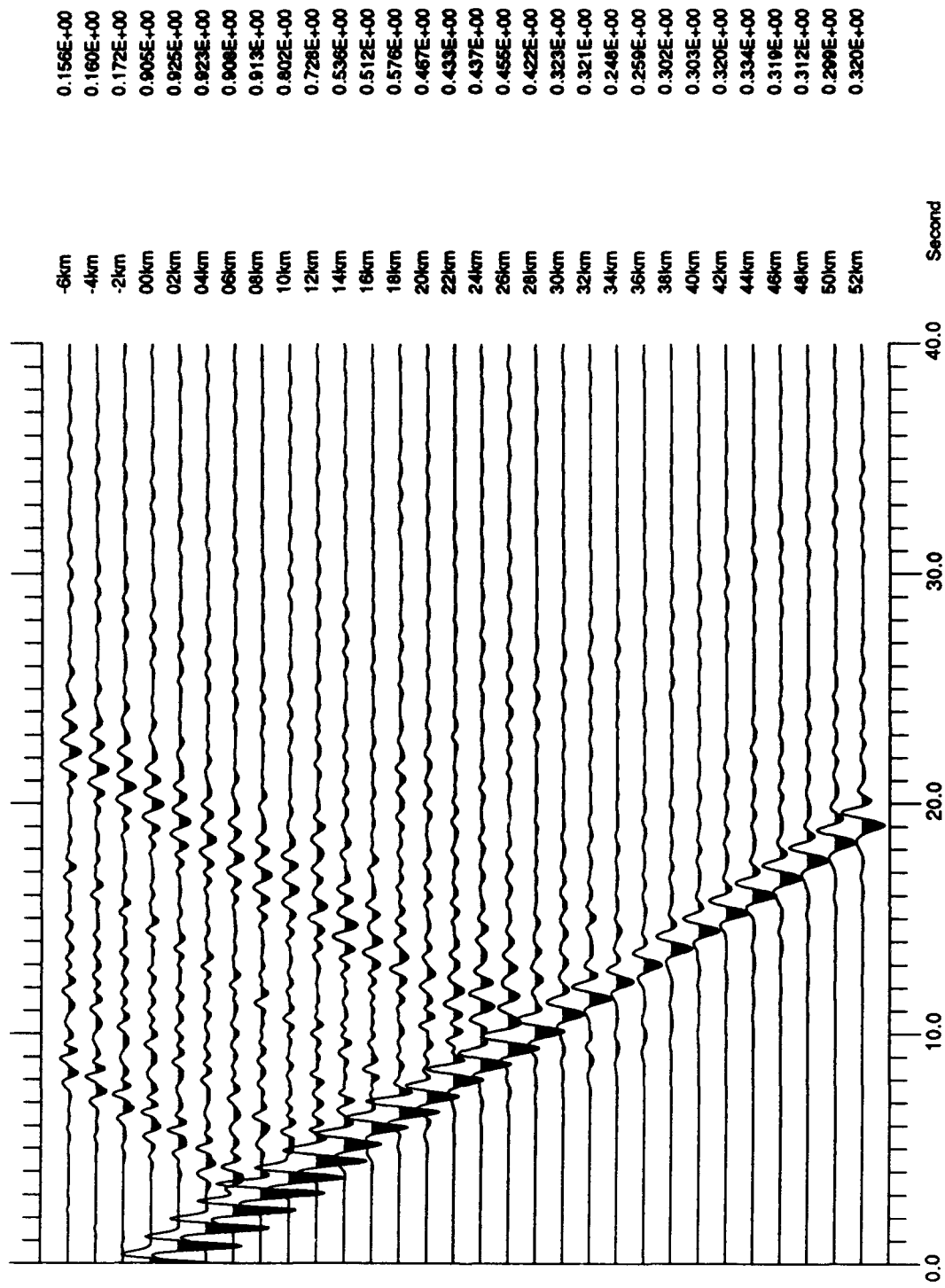
VERT, same scale, decimated by 5

Figure 54

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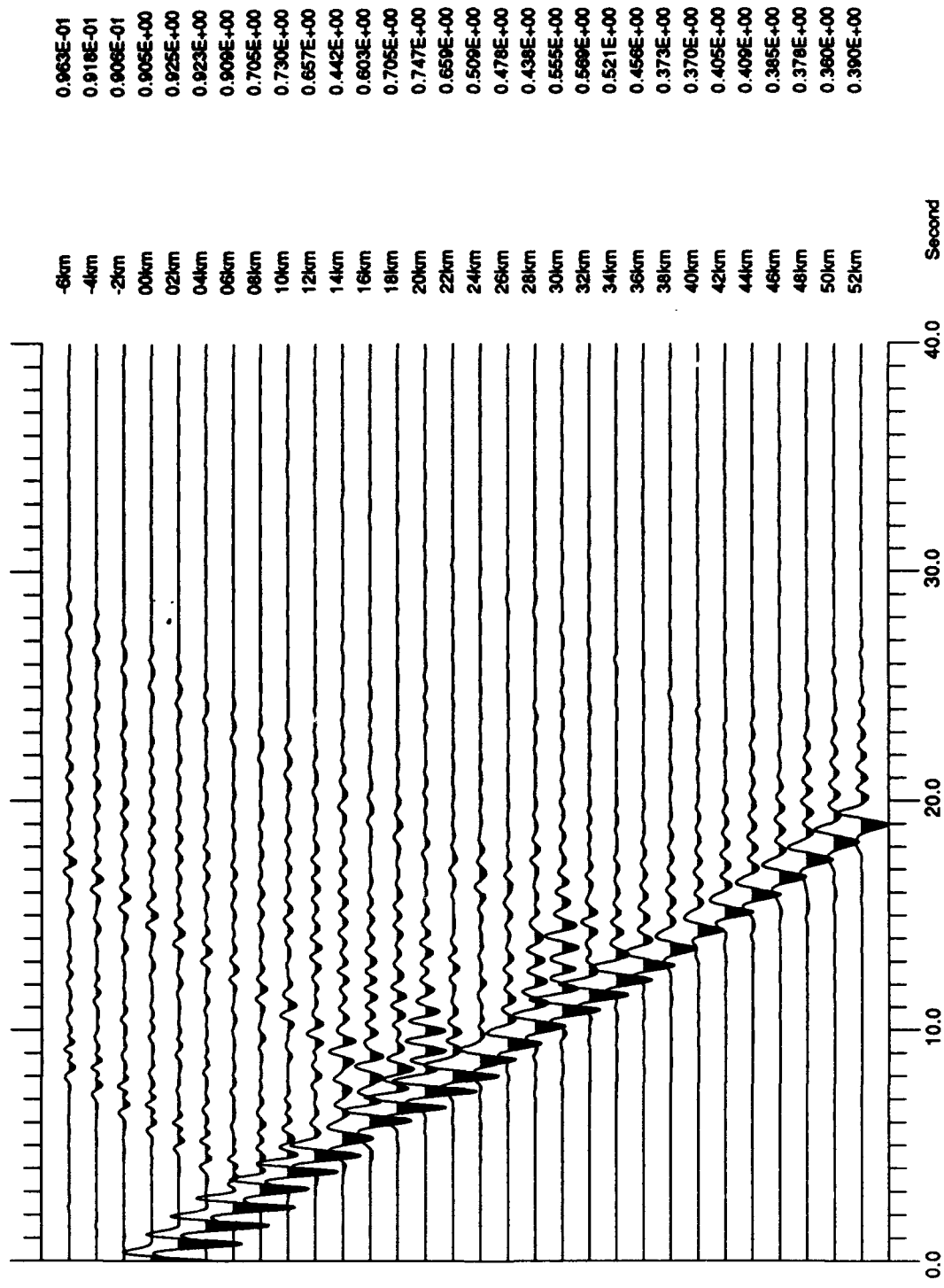
• •



Profile 53(seed 86037, Pr(1)=0.25), Surface Sensors

VERT, same scale, decimated by 5

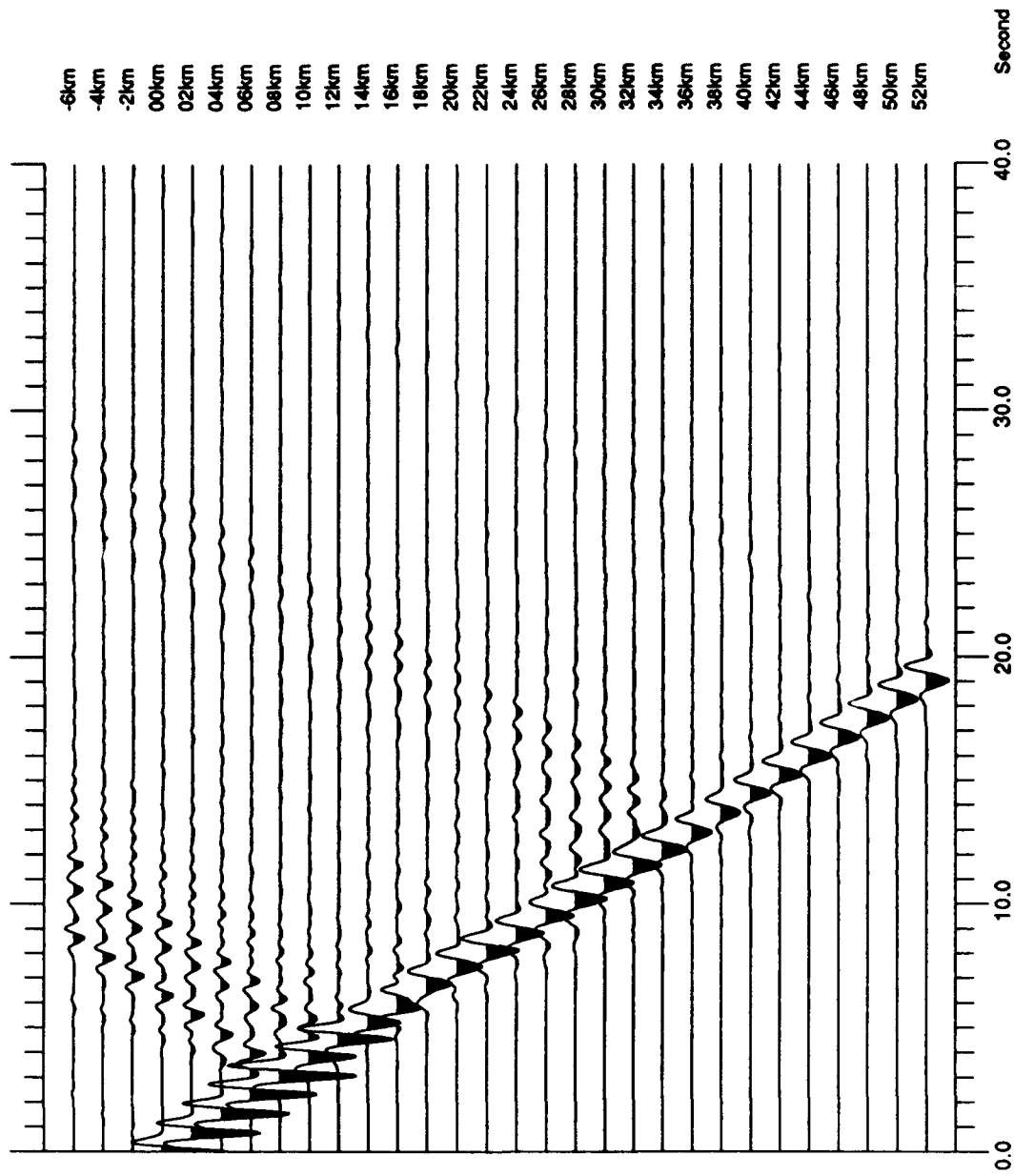
Figure 57



Profile 61 (seed 93459, Pr(1)=0.30), Surface Sensors

Figure 58

1 1
2 1
3 1
4 1
5 1
6 1
7 1
8 1
9 1
10 1
11 1
12 1
13 1
14 1
15 1
16 1
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29 1
30 1



0.144E+00
0.150E+00
0.150E+00
0.905E+00
0.925E+00
0.923E+00
0.909E+00
0.105E+01
0.639E+00
0.741E+00
0.440E+00
0.315E+00
0.337E+00
0.336E+00
0.431E+00
0.365E+00
0.378E+00
0.431E+00
0.401E+00
0.376E+00
0.333E+00
0.270E+00
0.255E+00
0.277E+00
0.299E+00
0.302E+00
0.299E+00
0.294E+00
0.281E+00
0.308E+00

Profile 62(seed 93468, Pr(1)=0.30), Surface Sensors

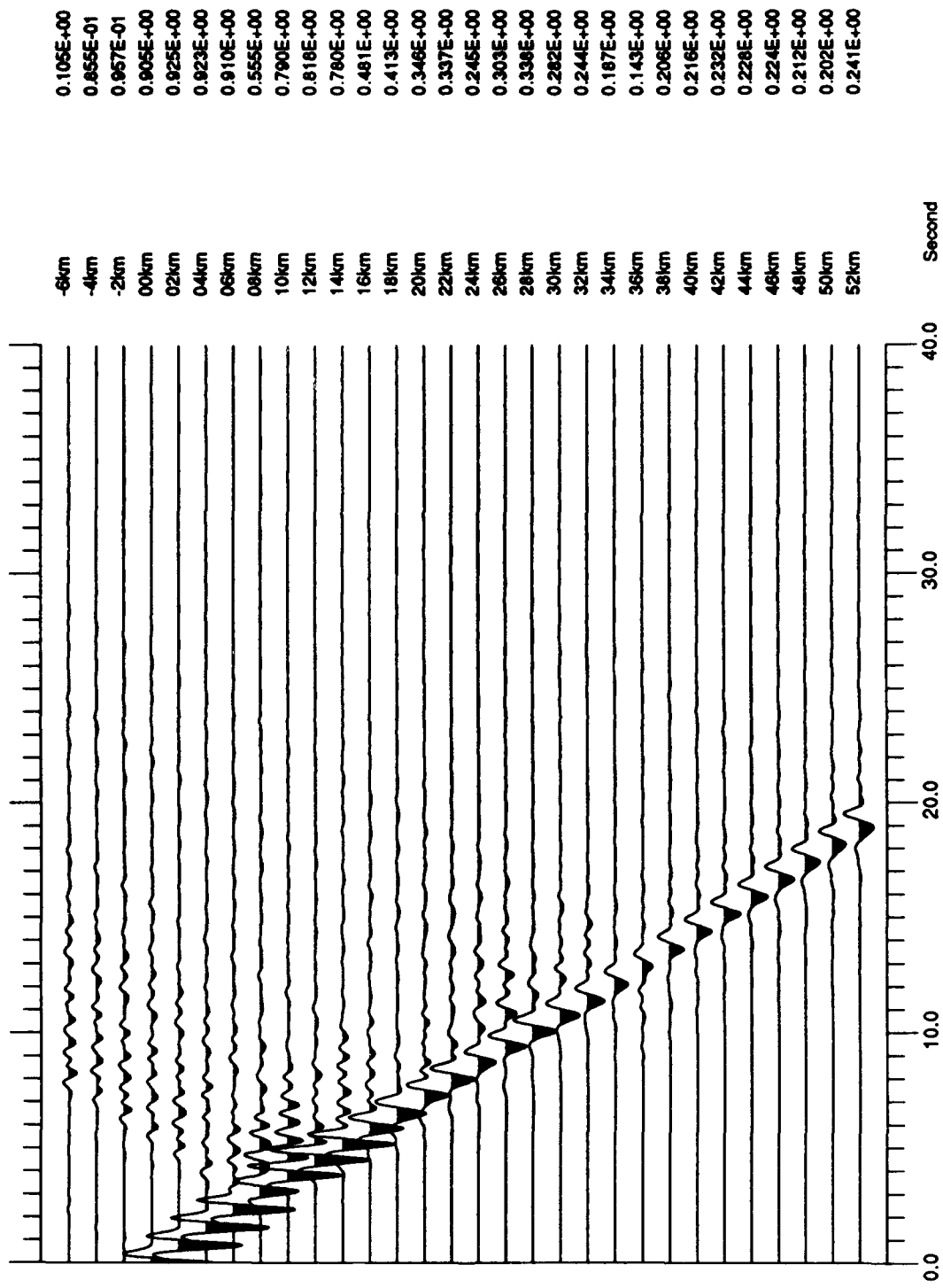
VERT, same scale, decimated by 5

Figure 59

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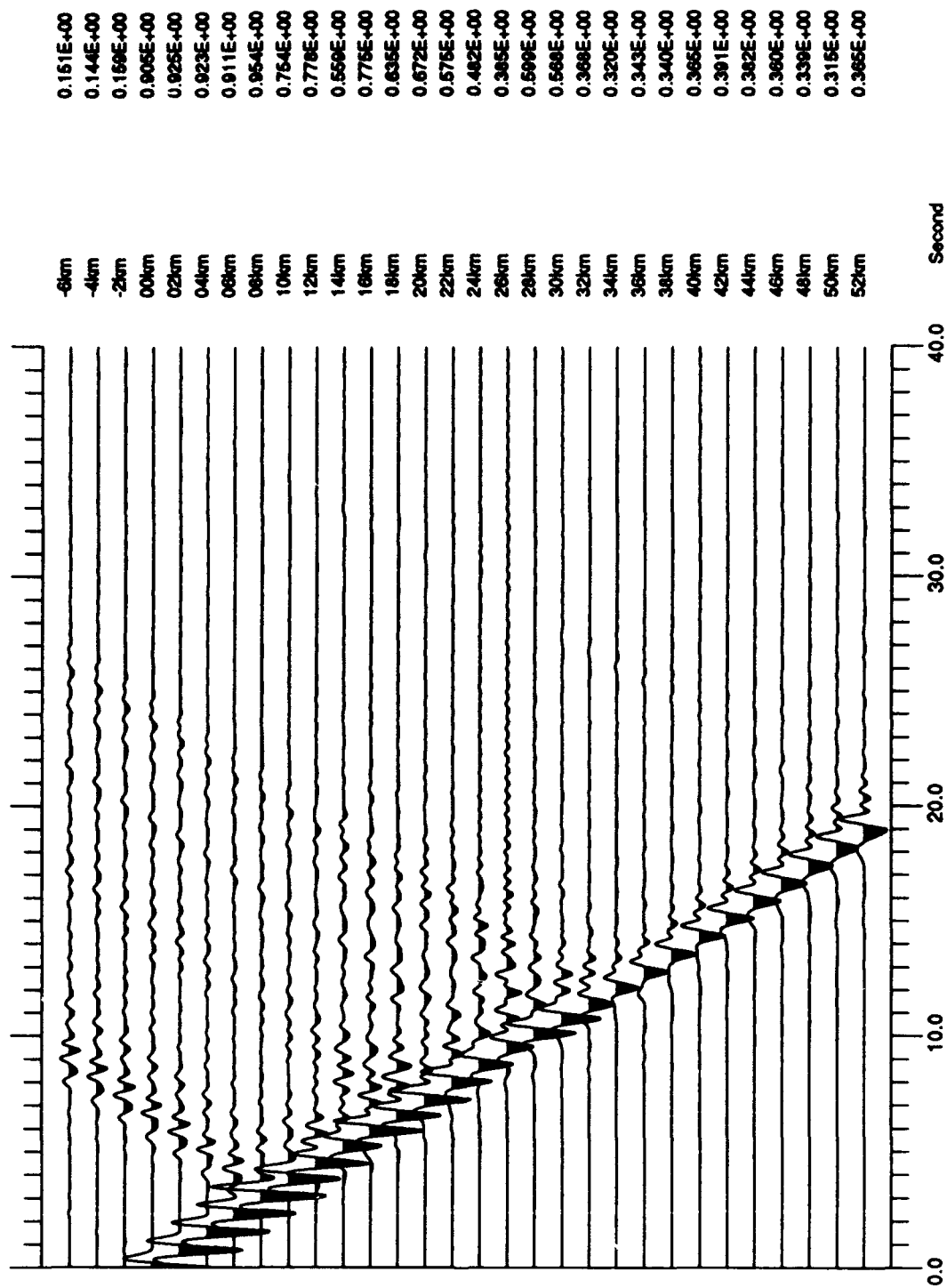
• • •



Profile 64(seed 55473, Pr(1)=0.32), Surface Sensors

Figure 61

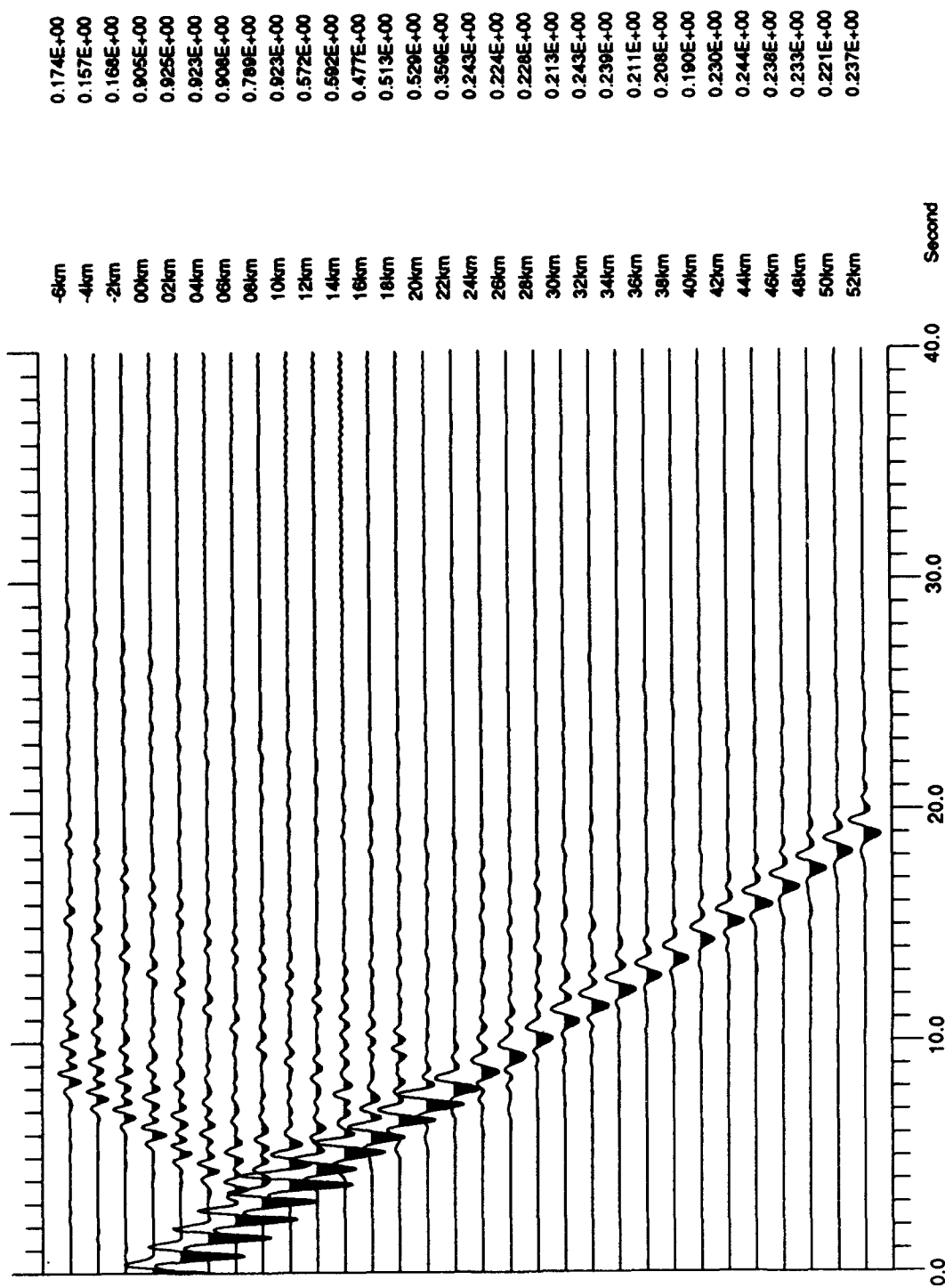
VERT, same scale, decimated by 5



Profile 65(seed 55499, Pr(1)=0.32), Surface Sensors

VERT, same scale, decimated by 5

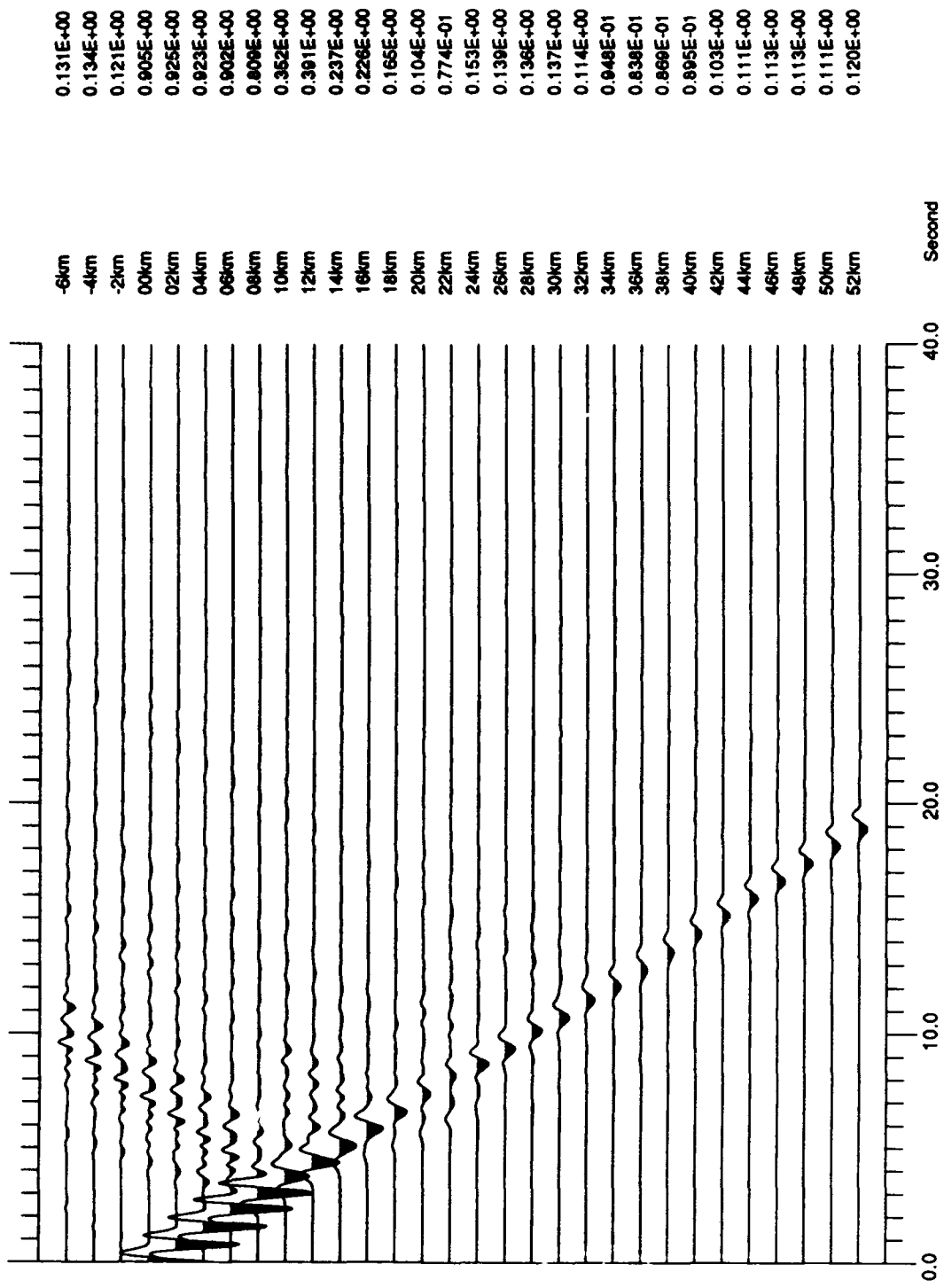
Figure 62



Profile 71 (seed 22192, $Pr(1)=0.35$), Surface Sensors

Figure 64

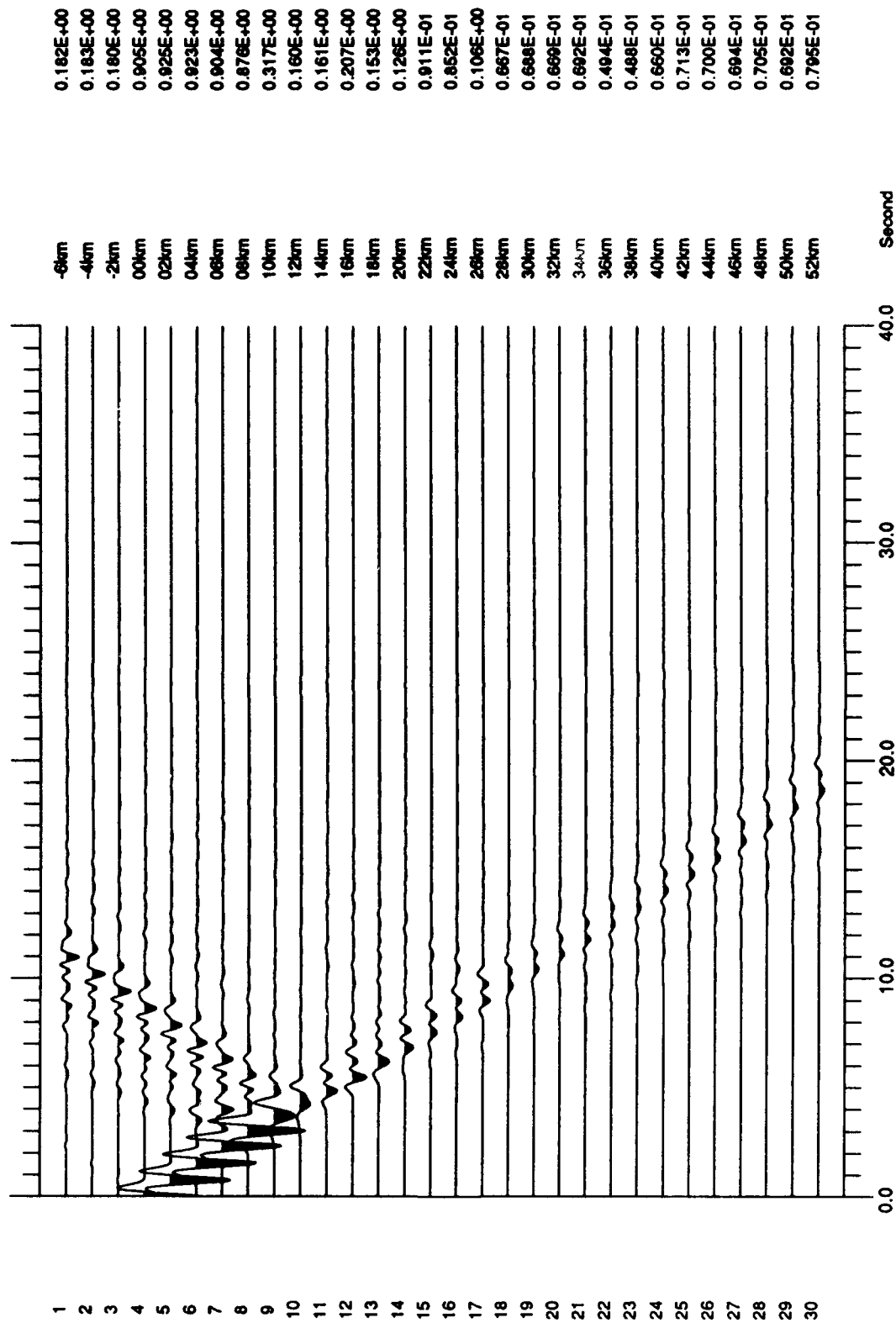
VERT, same scale, decimated by 5



Profile 72(seed 31087, Pr(1)=0.35), Surface Sensors

VERT, same scale, decimated by 5

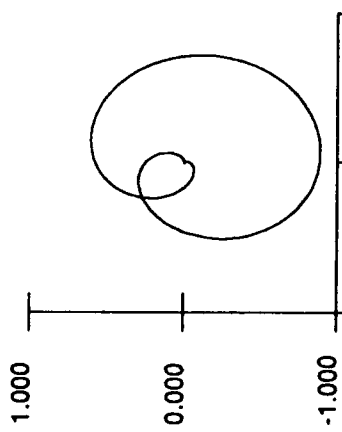
Figure 65



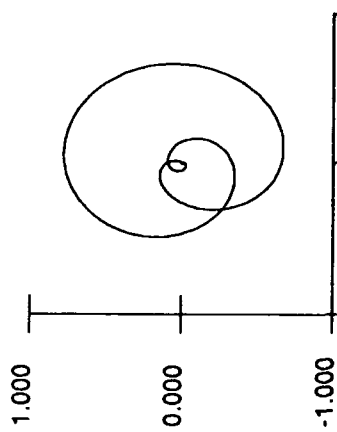
Profile 73(seed 86061, Pr(1)=0.35), Surface Sensors

VERT, same scale, decimated by 5

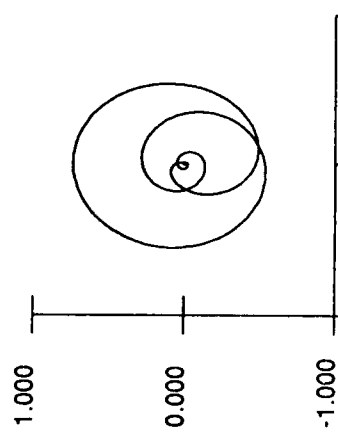
Figure 66



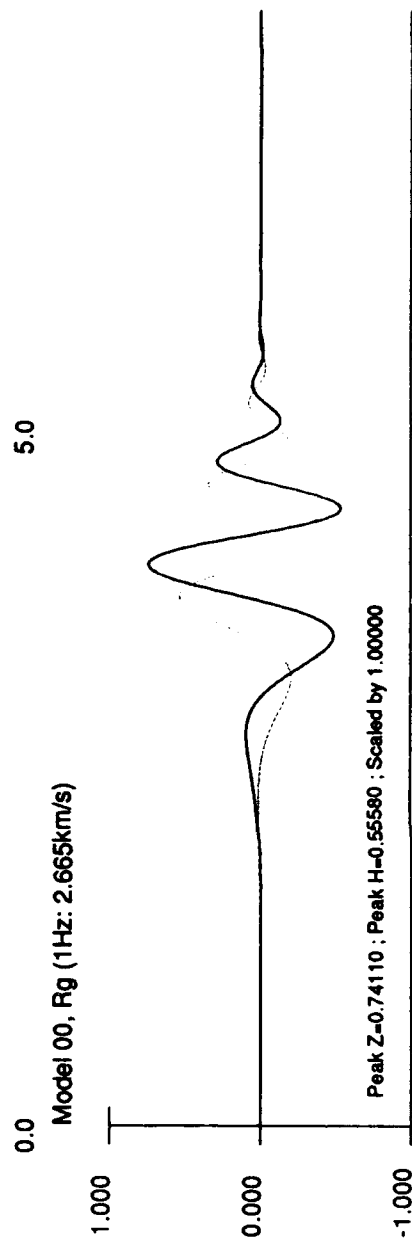
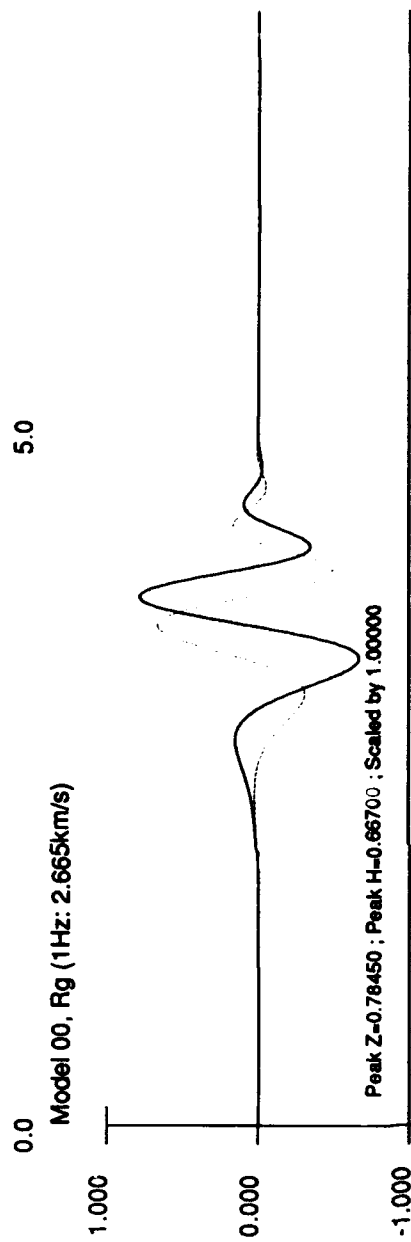
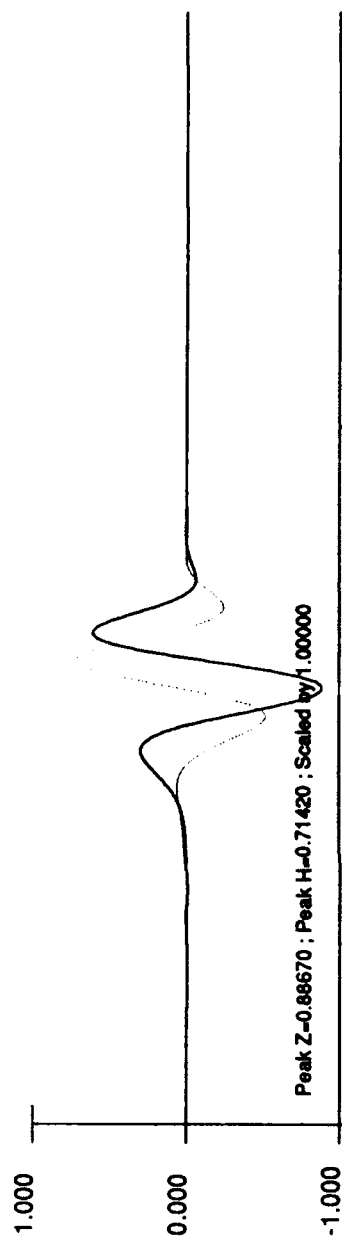
Particle Motion, Trace 8



Particle Motion, Trace 16



Particle Motion, Trace 24



Model 00, Rg (1Hz: 2.665km/s)

Figure 67

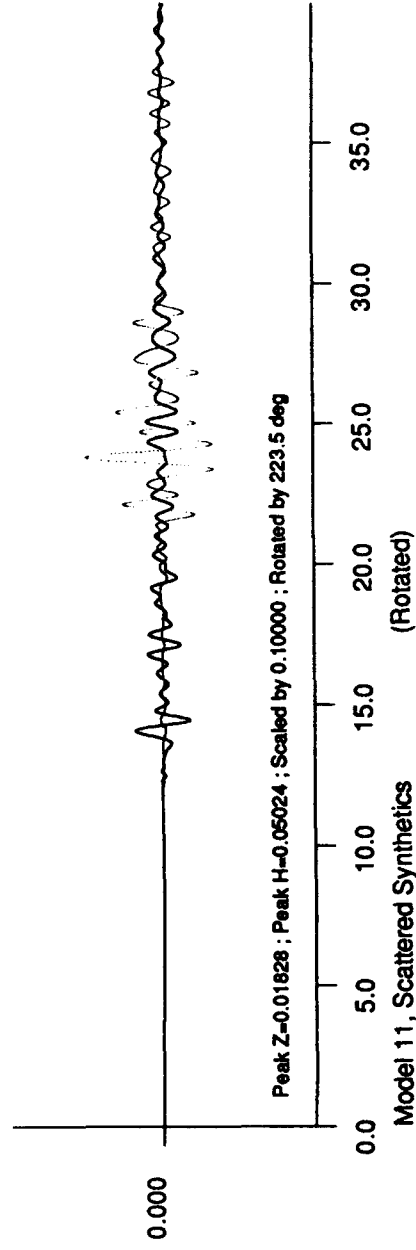
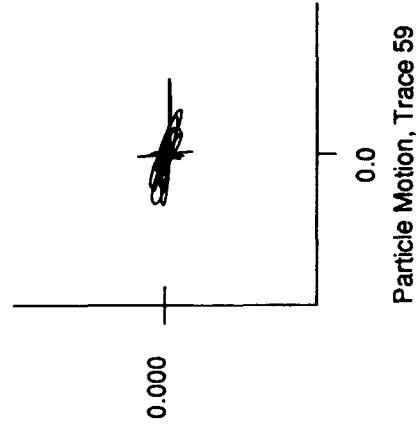
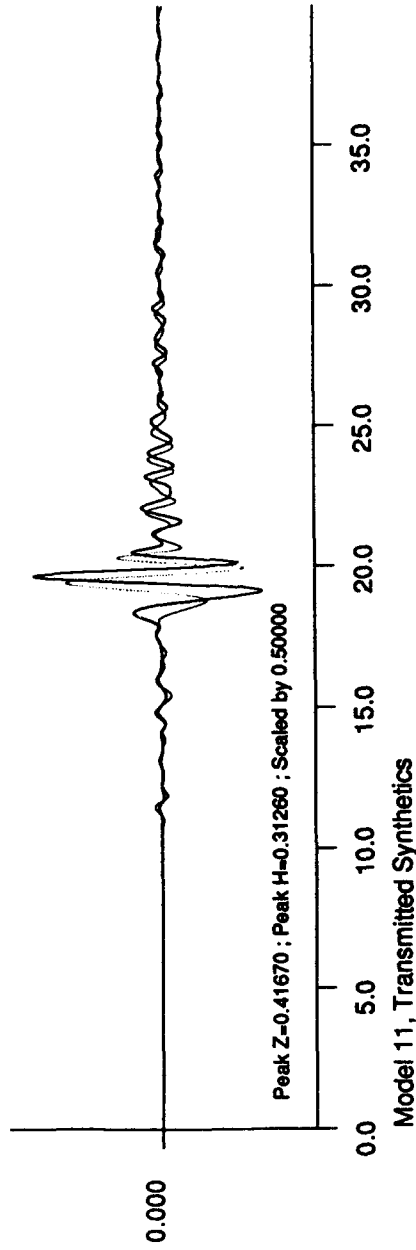
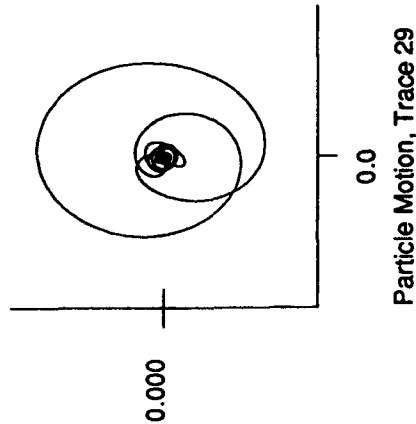
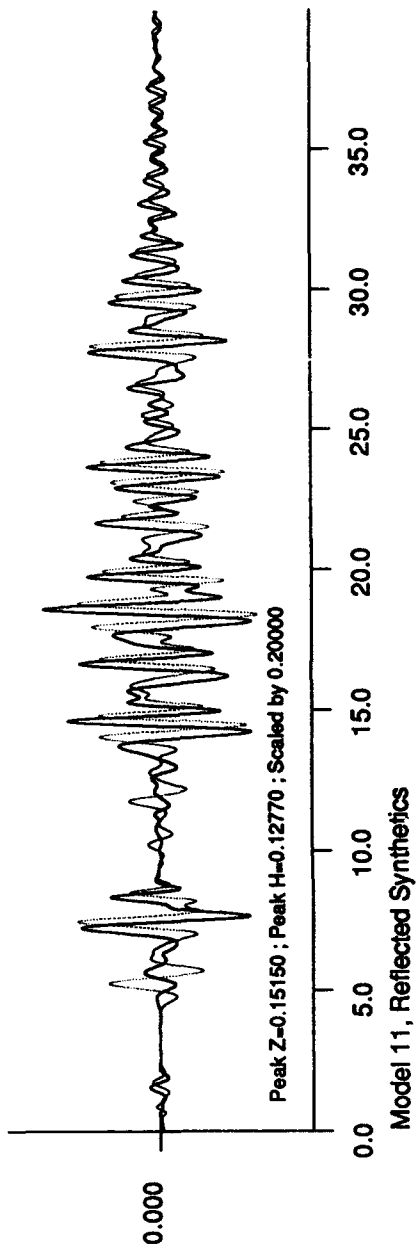
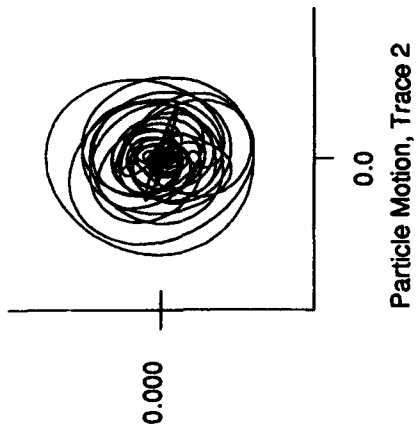
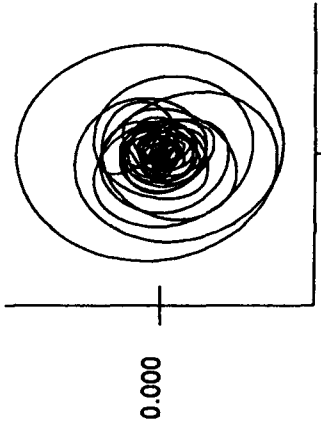


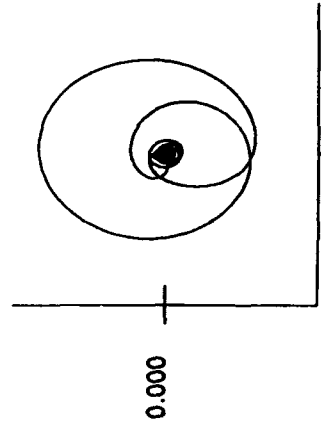
Figure 68

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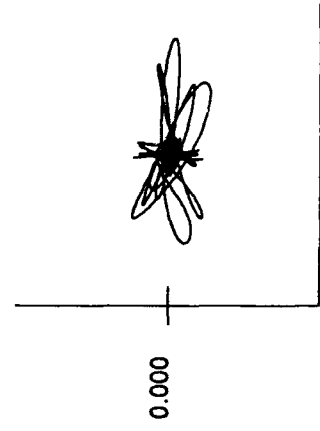
• • • • •



Particle Motion, Trace 2



Particle Motion, Trace 29



Particle Motion, Trace 59

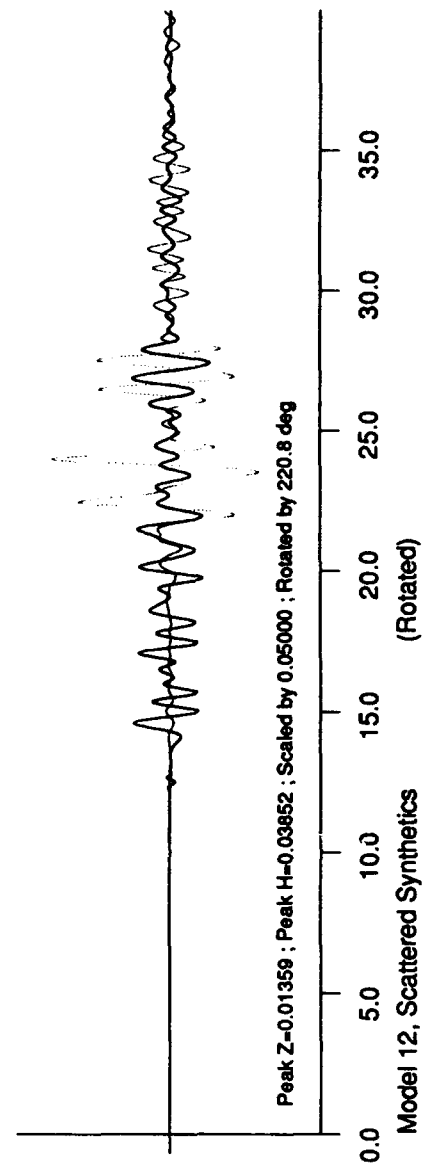
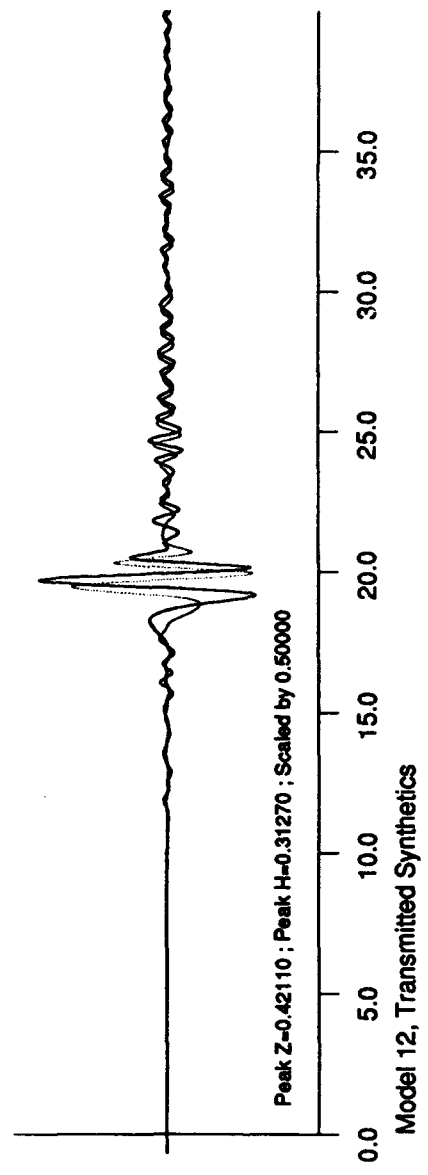
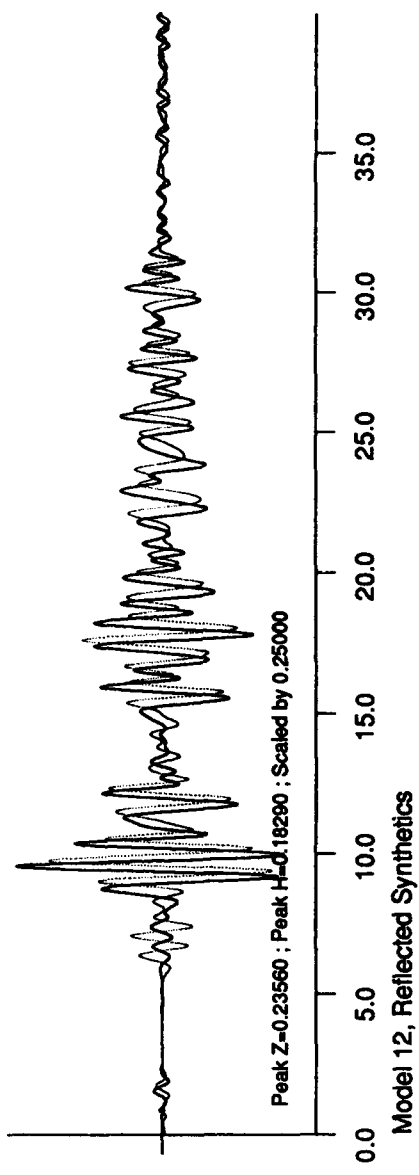


Figure 69

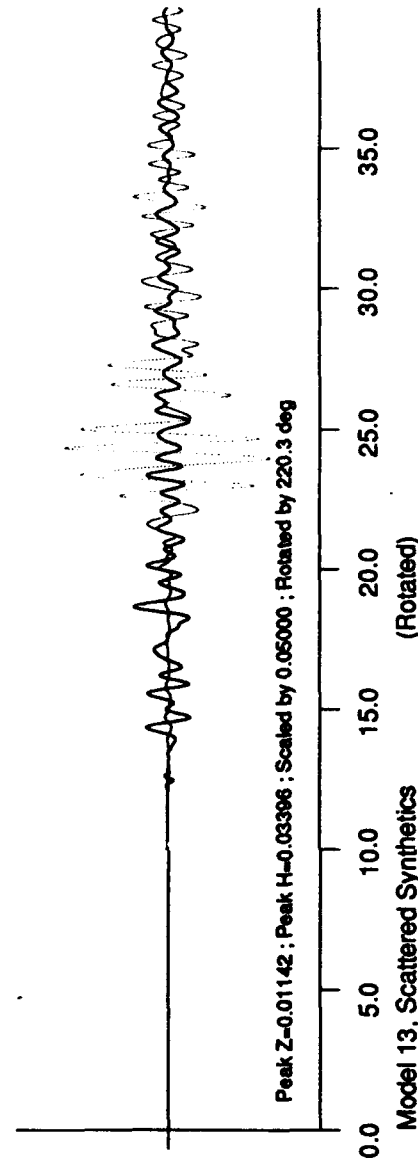
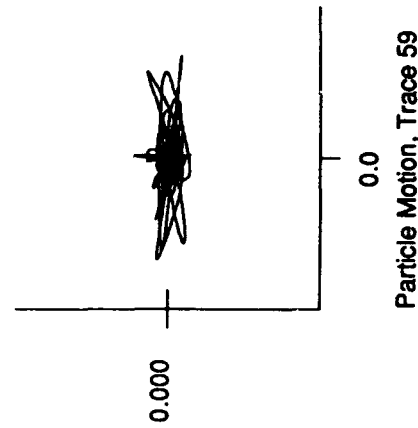
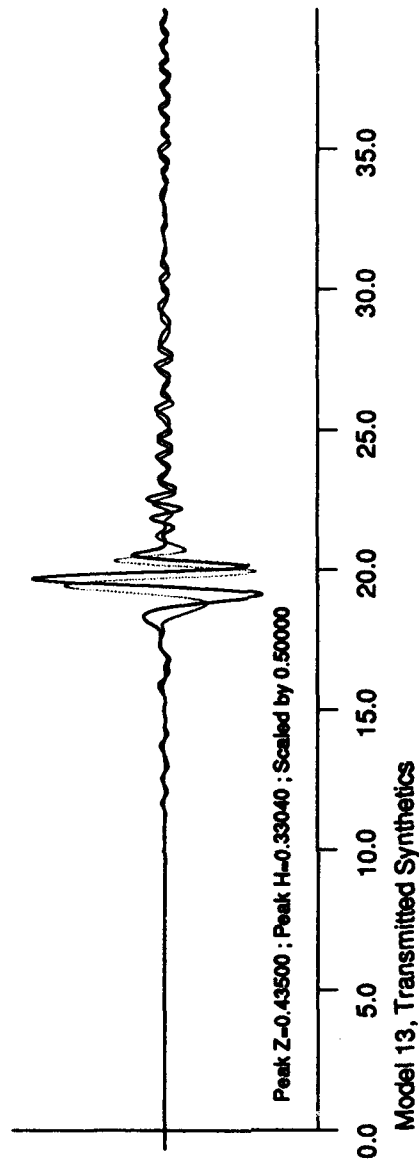
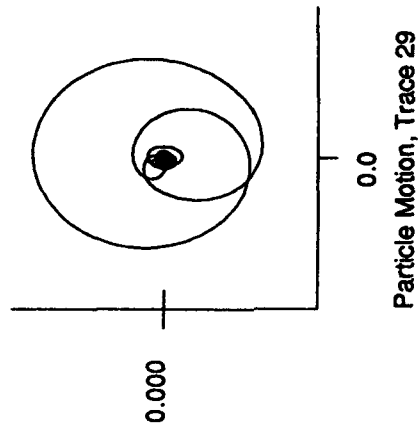
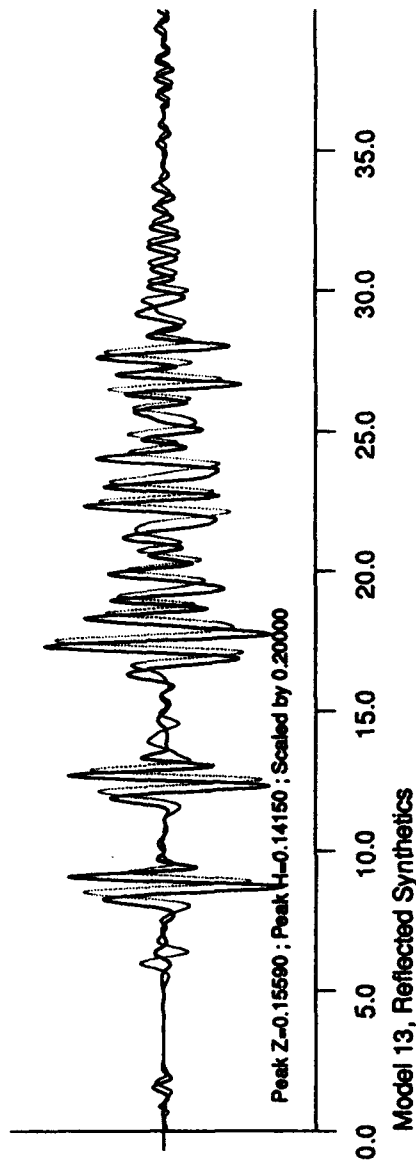
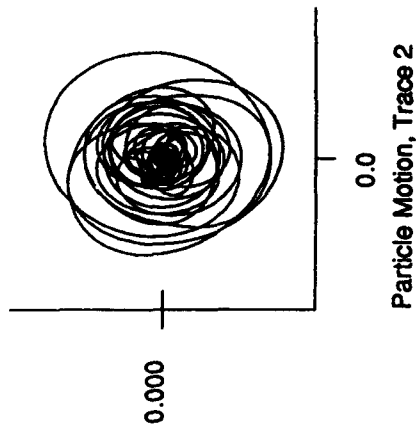


Figure 70

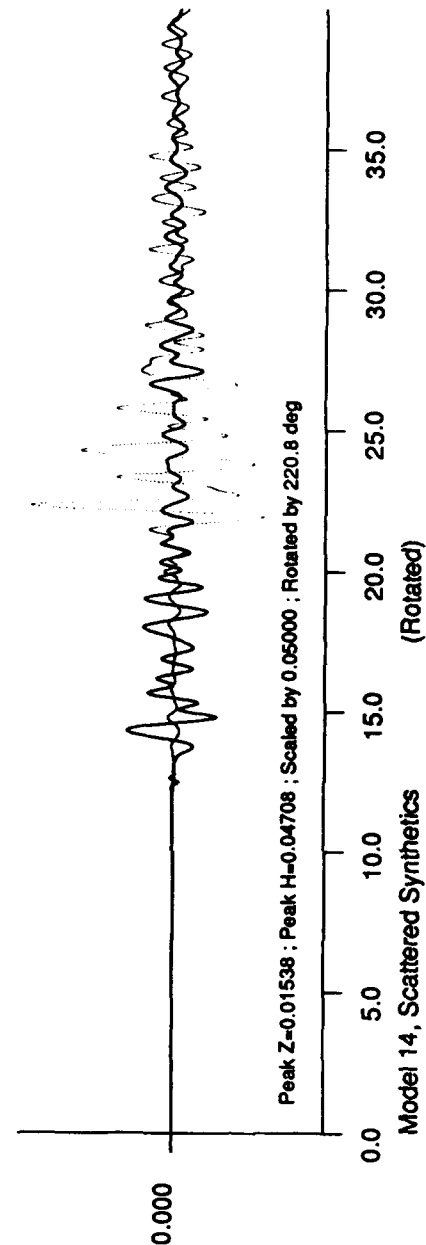
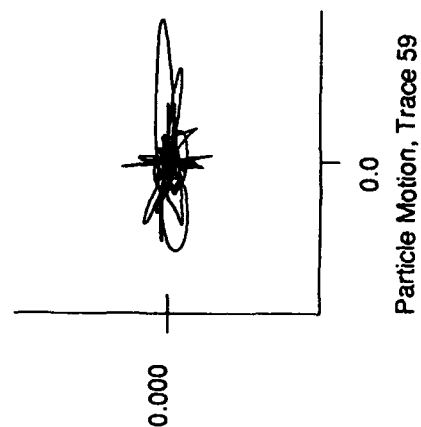
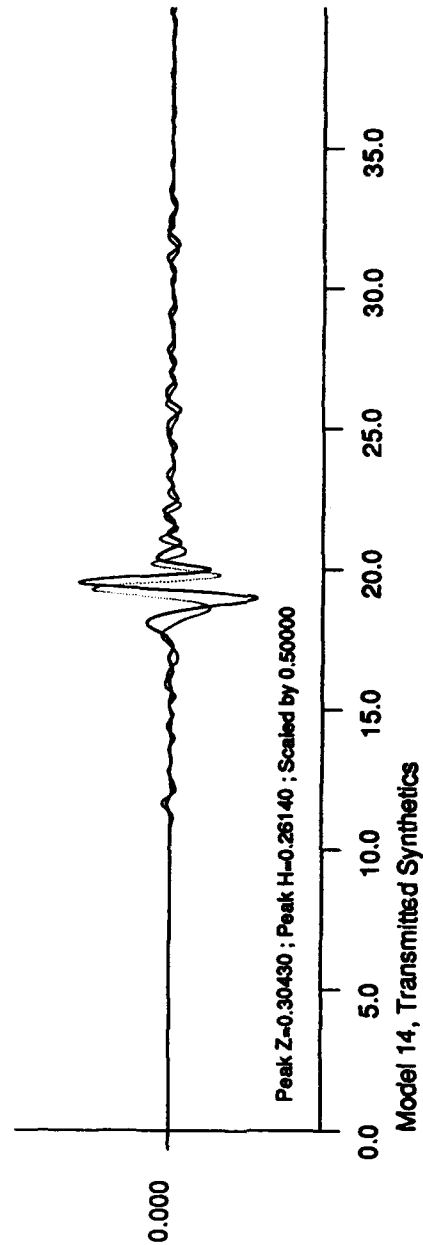
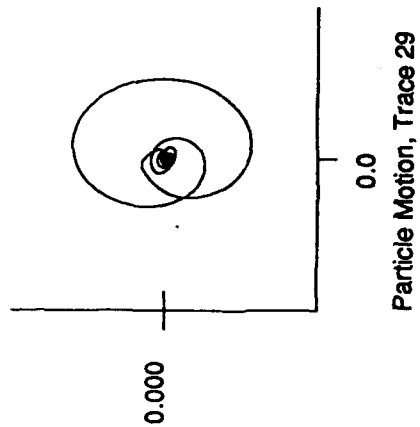
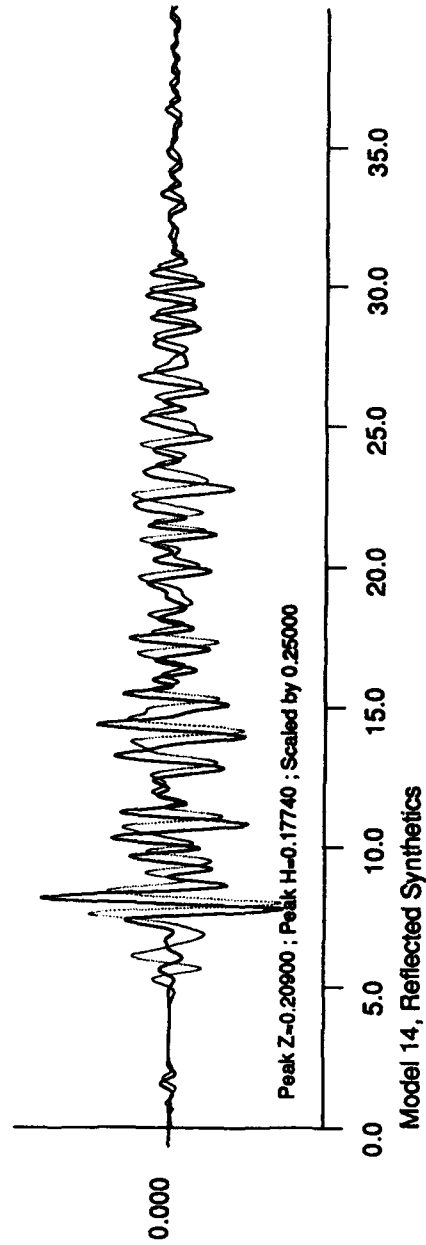
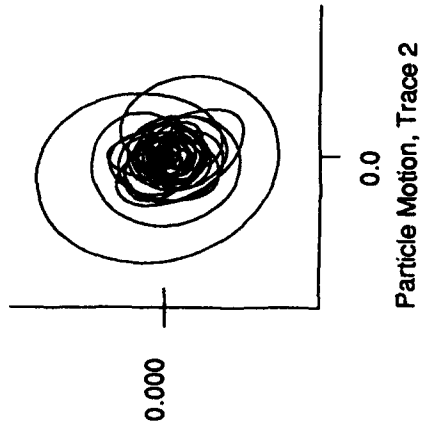
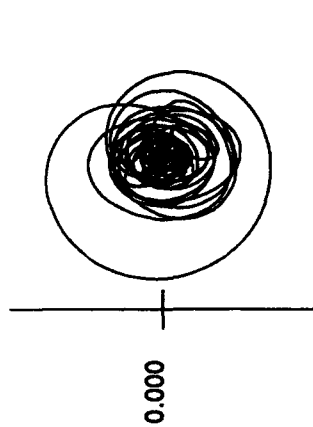
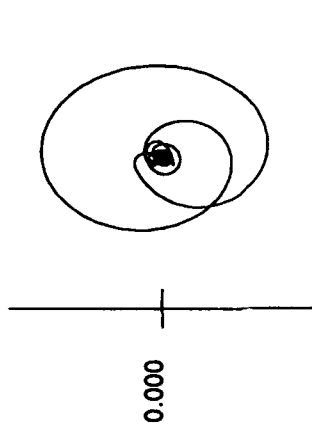
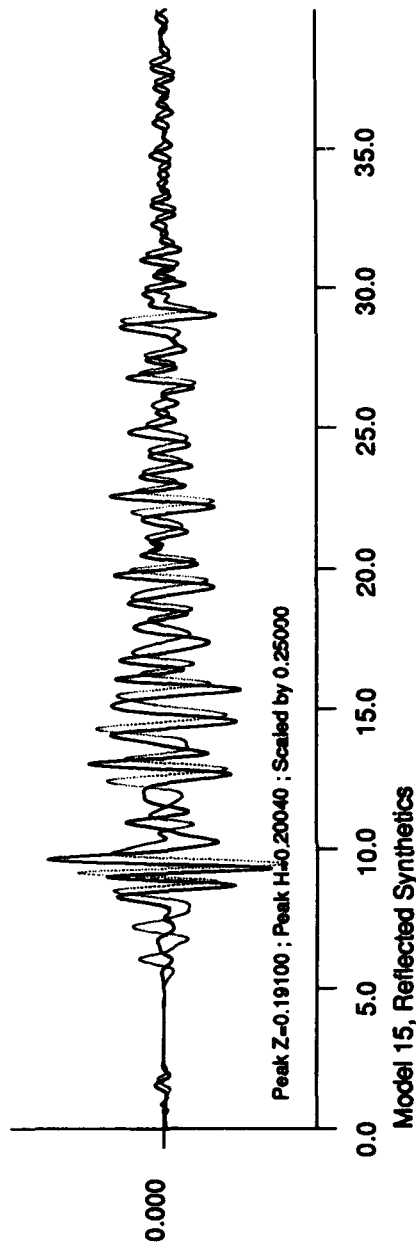


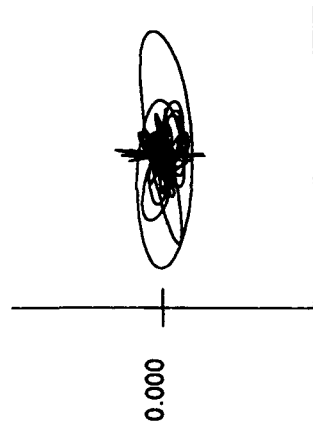
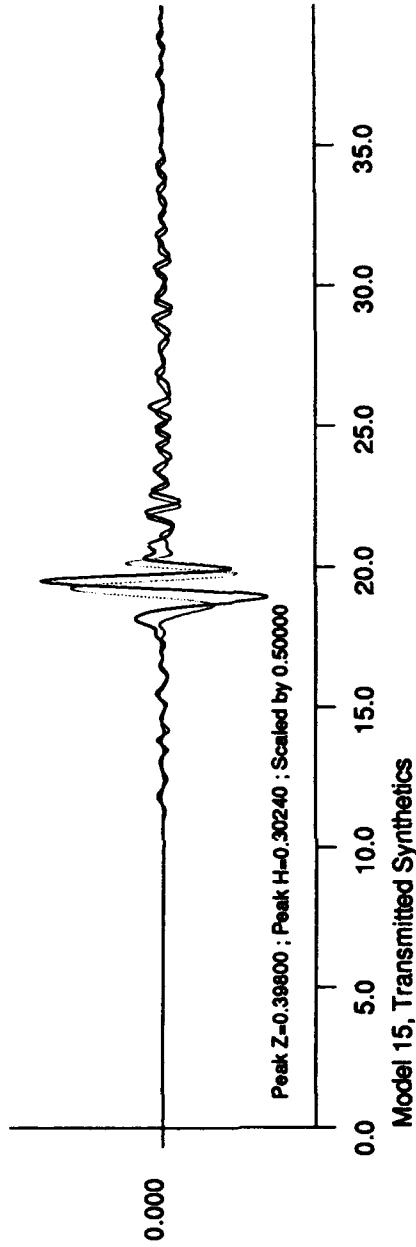
Figure 71



Particle Motion, Trace 2



Particle Motion, Trace 29



Particle Motion, Trace 59

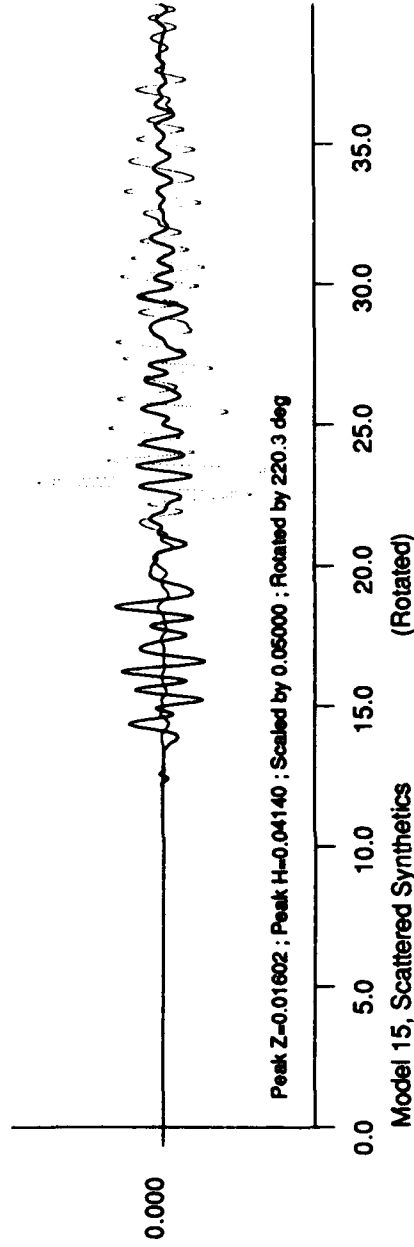
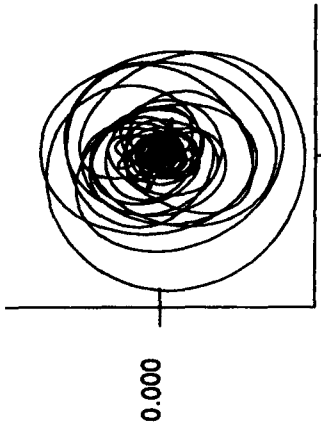


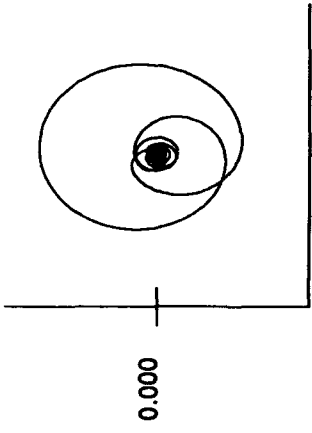
Figure 72

...

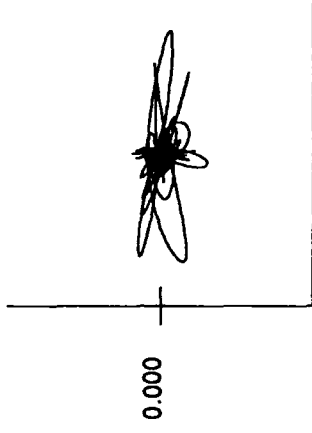
...



Particle Motion, Trace 2



Particle Motion, Trace 29



Particle Motion, Trace 59

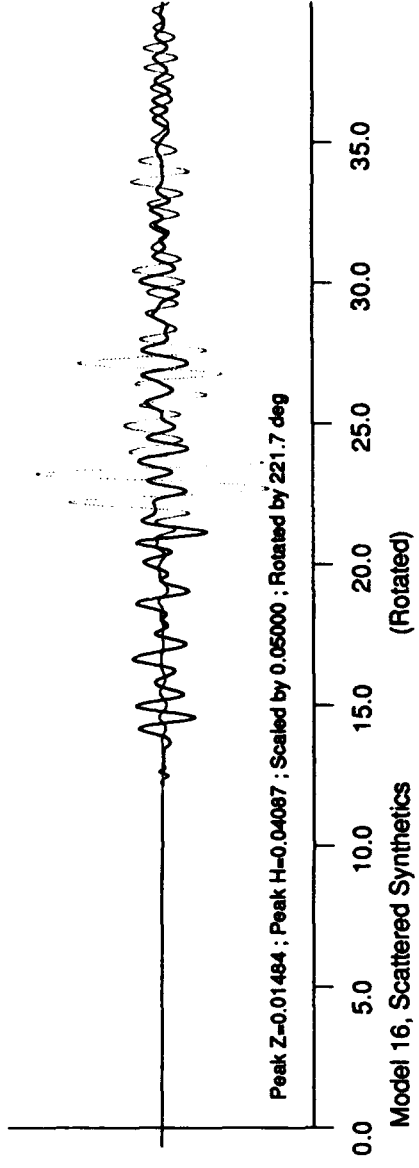
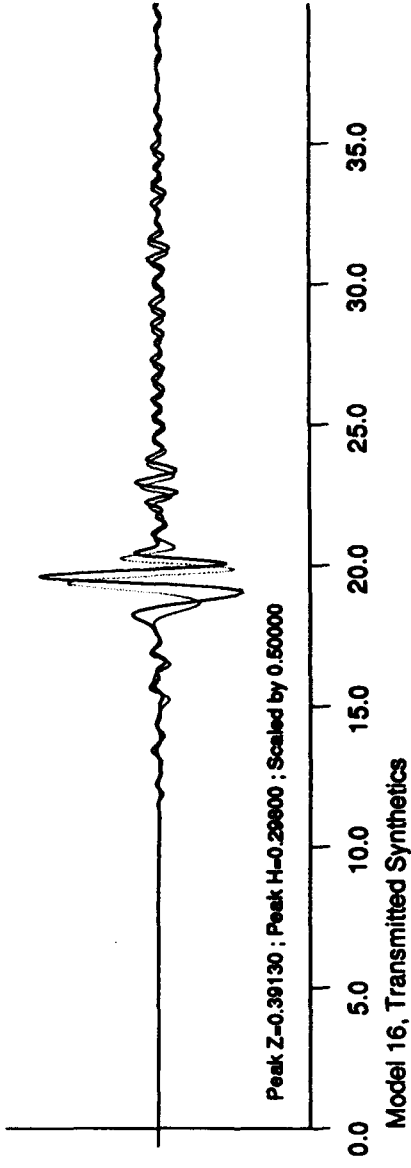
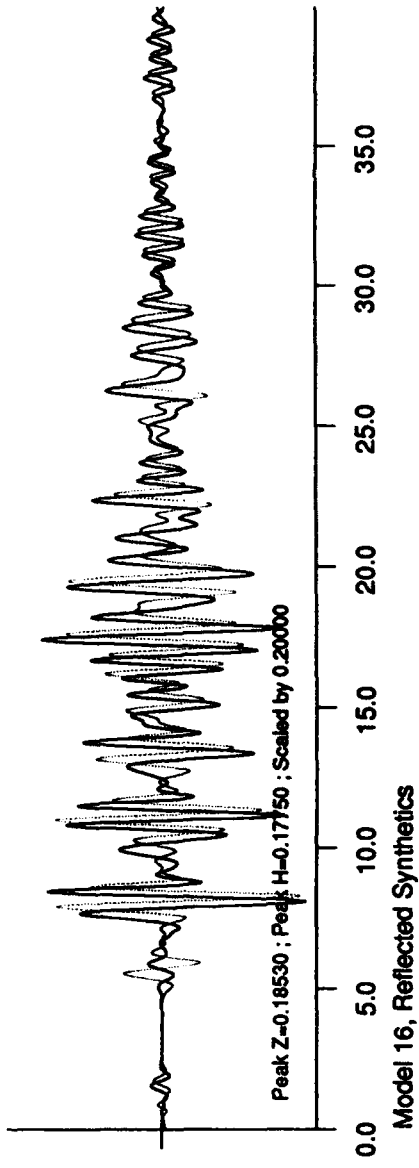
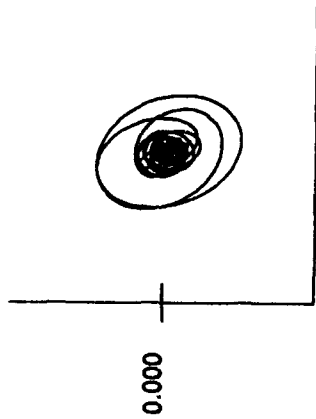
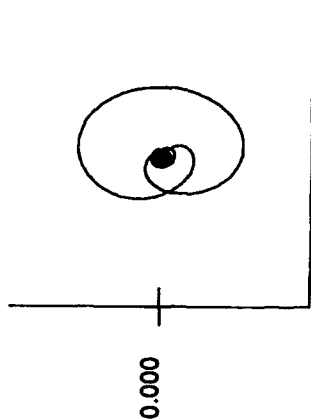


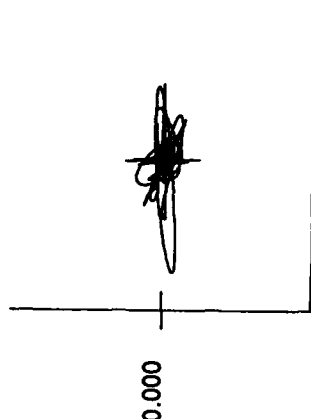
Figure 73



Particle Motion, Trace 2



Particle Motion, Trace 29



Particle Motion, Trace 59

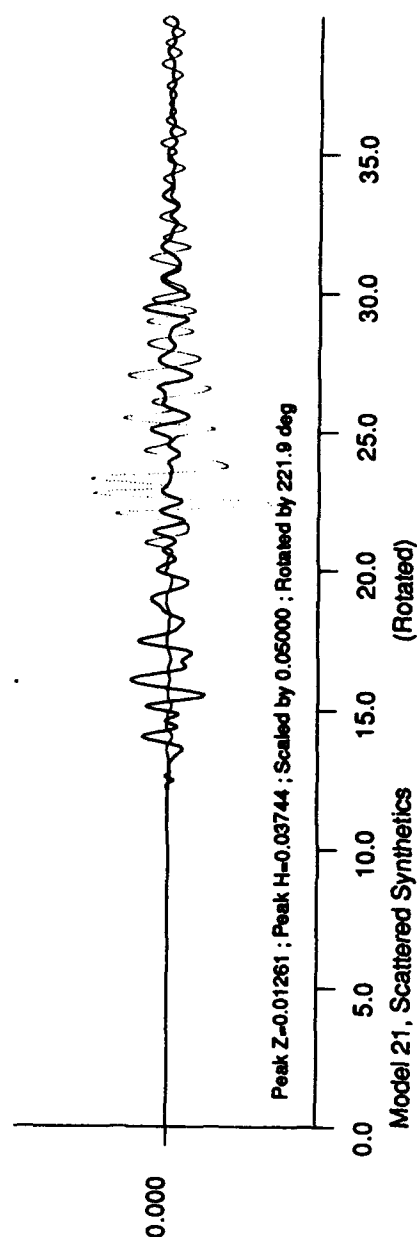
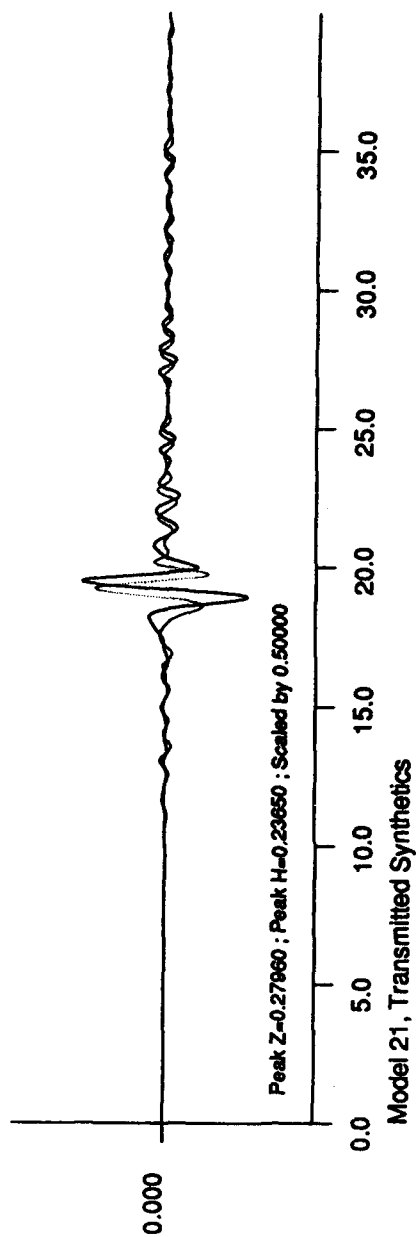
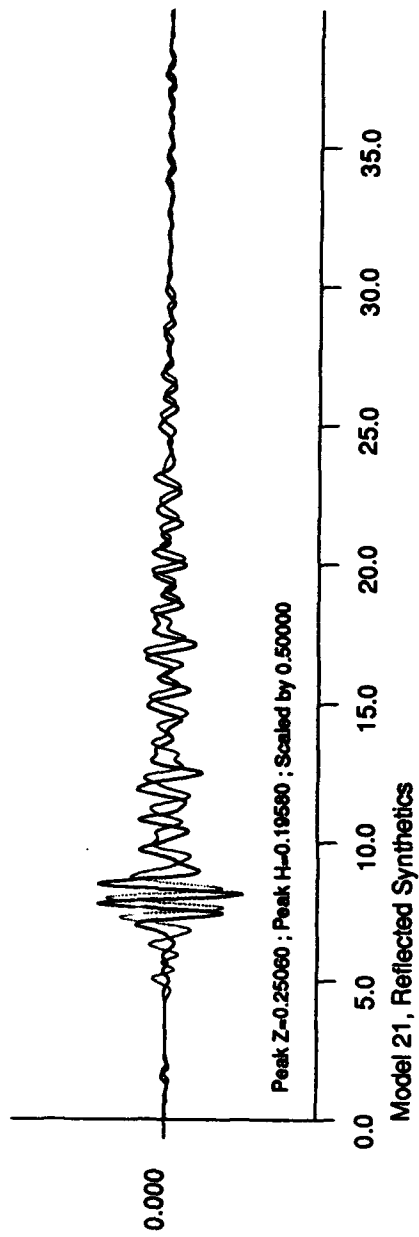
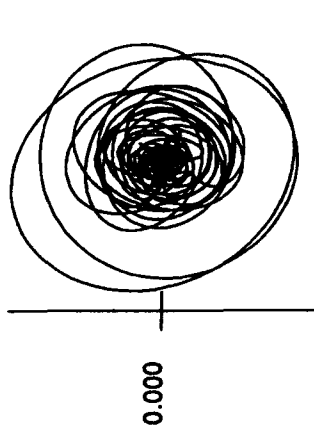
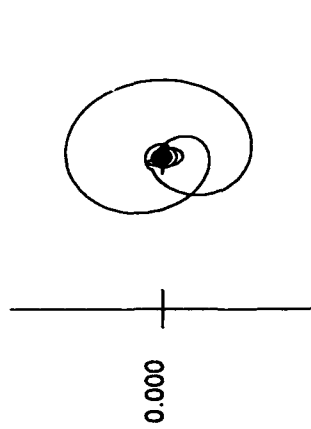


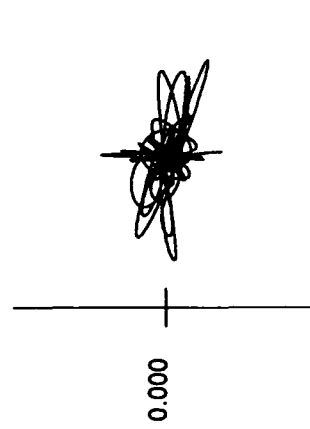
Figure 74



Particle Motion, Trace 2



Particle Motion, Trace 29



Particle Motion, Trace 59

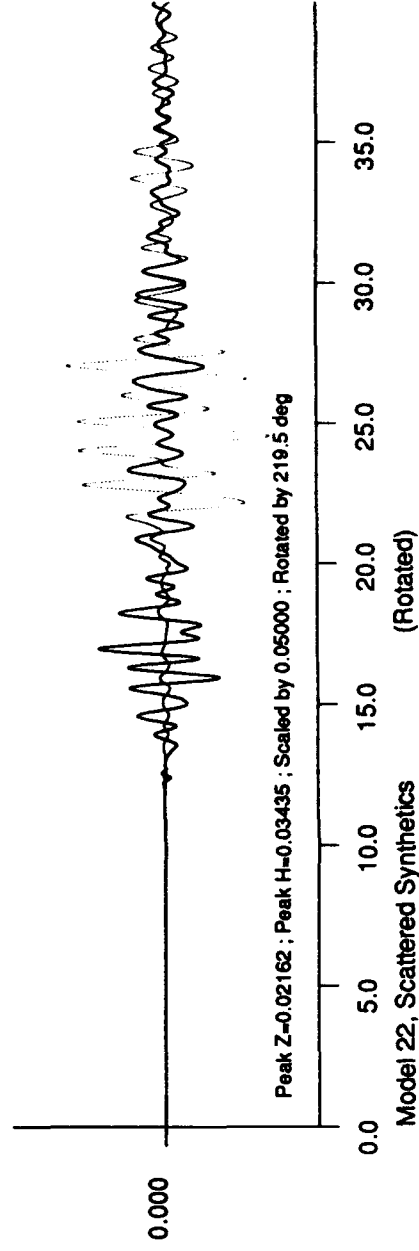
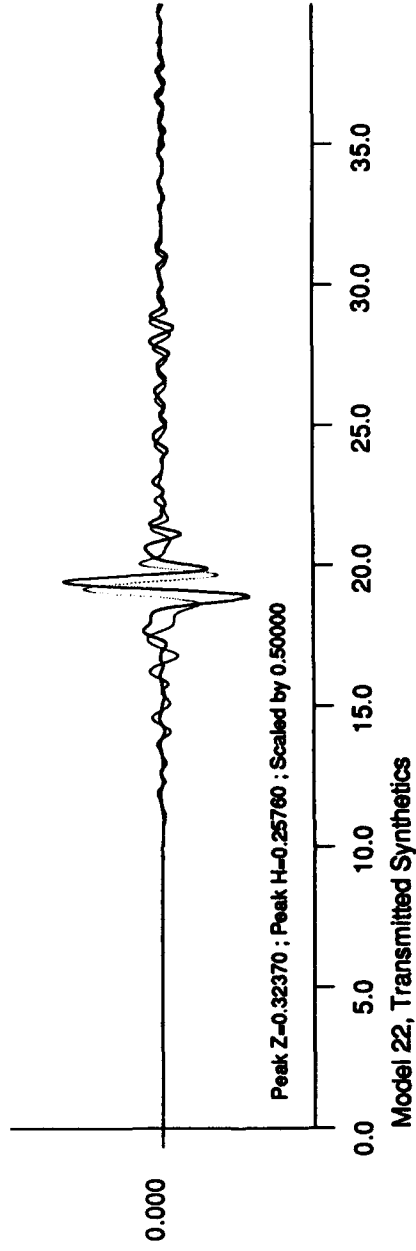
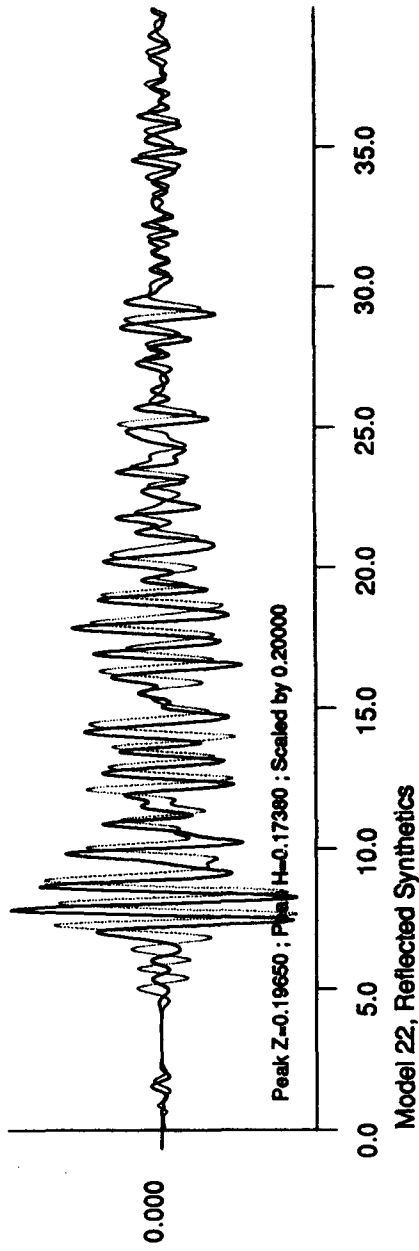
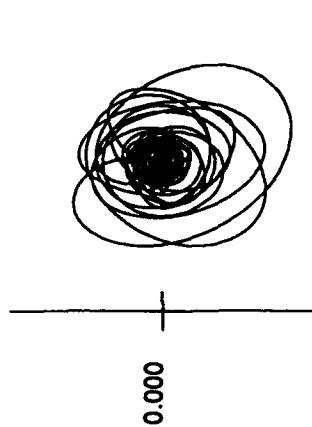
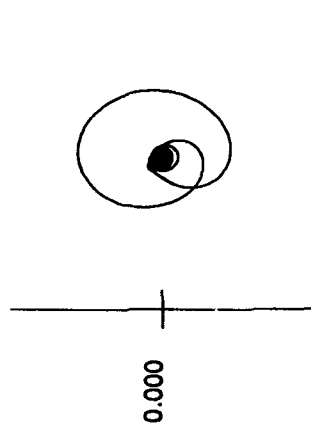


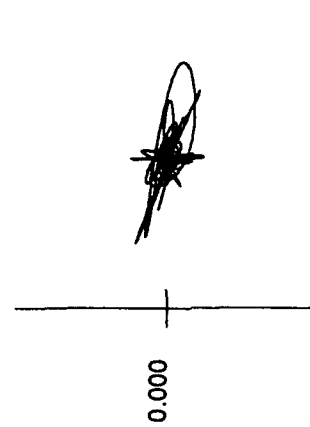
Figure 75



Particle Motion, Trace 2



Particle Motion, Trace 29



Particle Motion, Trace 59

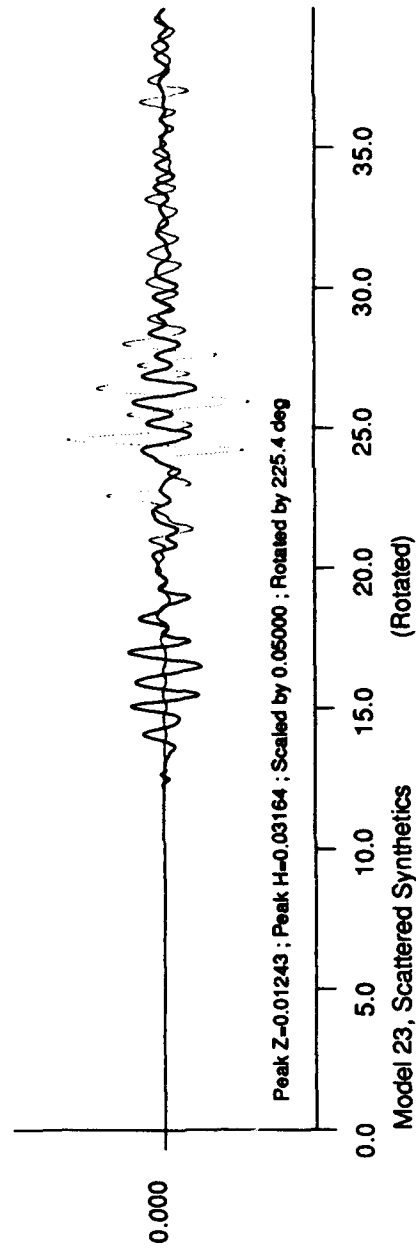
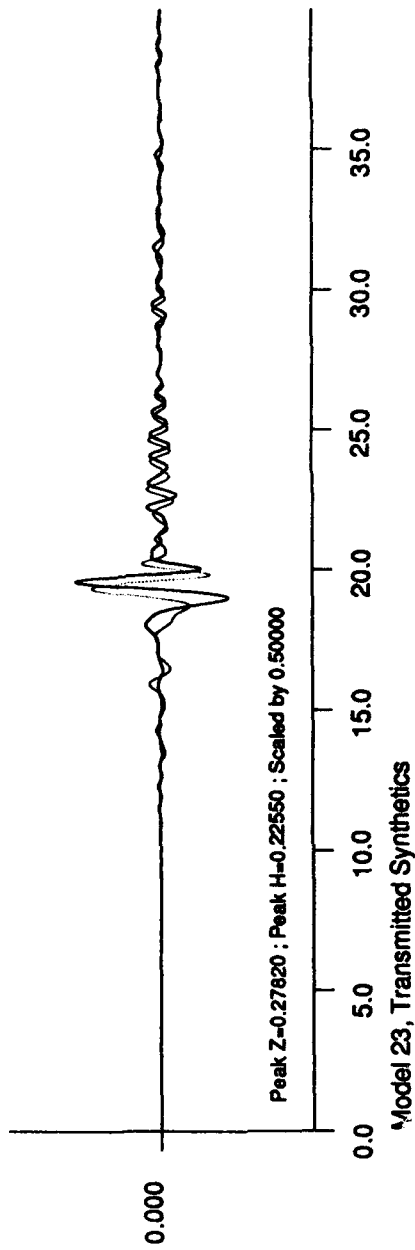
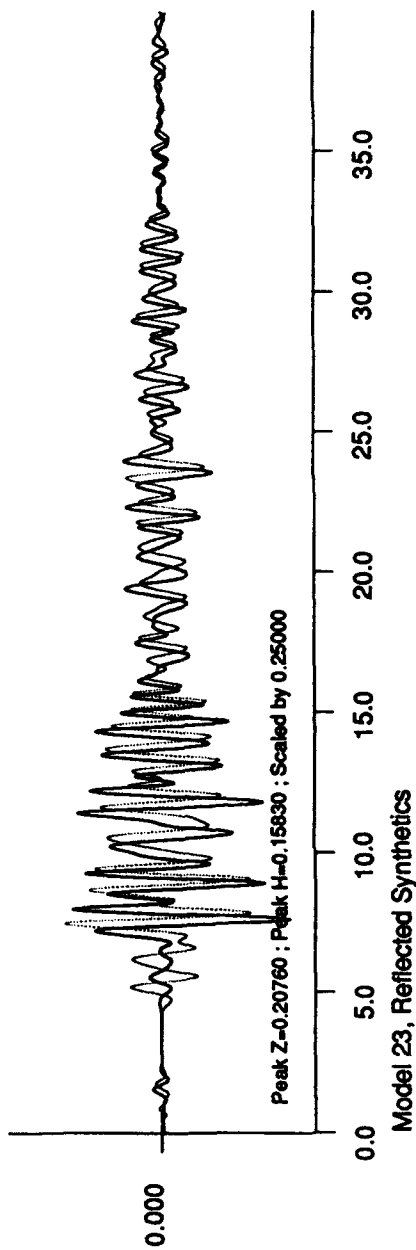
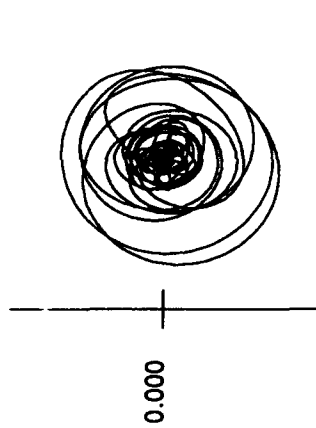
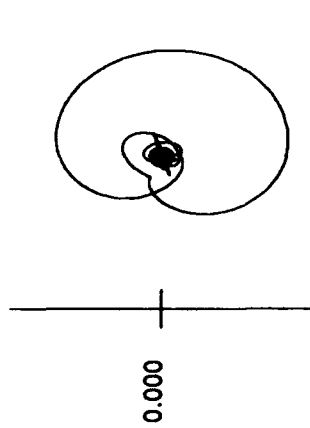


Figure 76

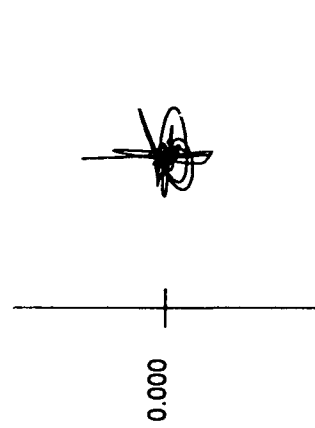
.. . . .



Particle Motion, Trace 2



Particle Motion, Trace 29



Particle Motion, Trace 59

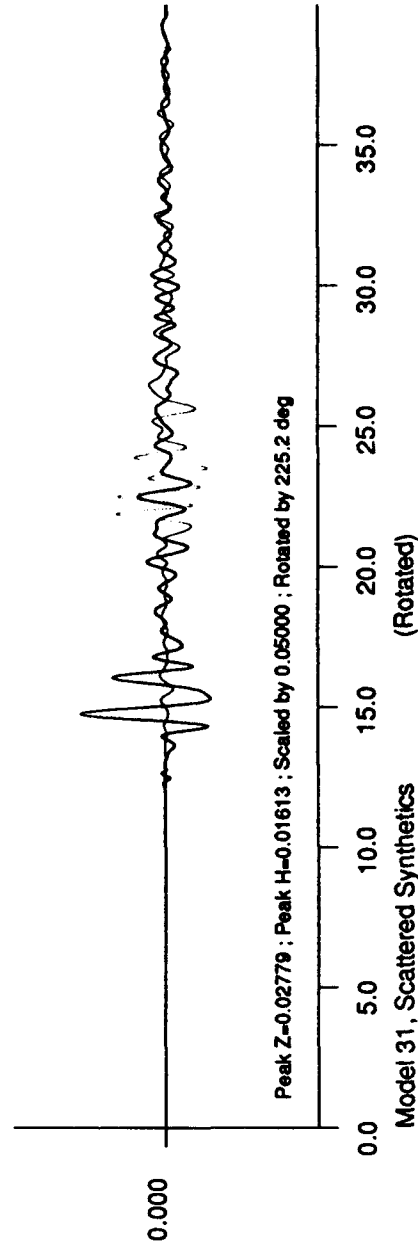
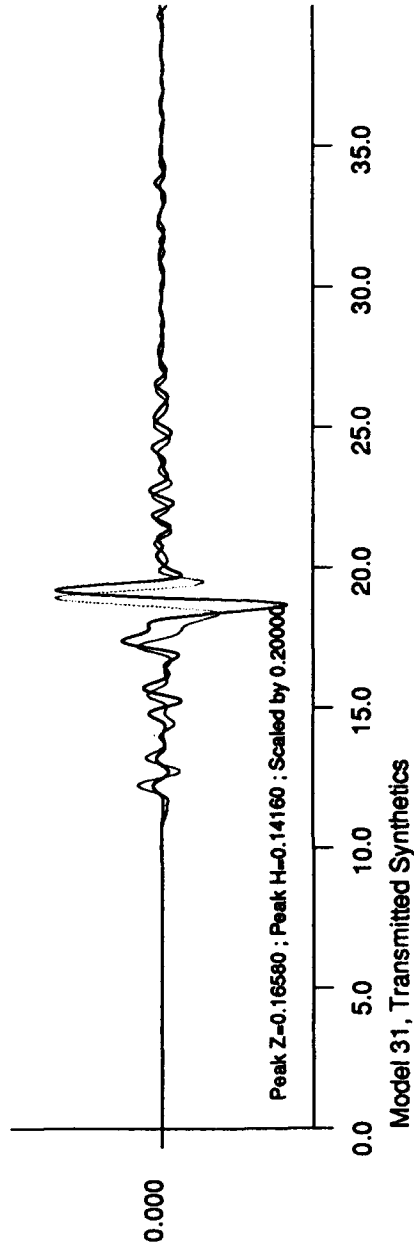
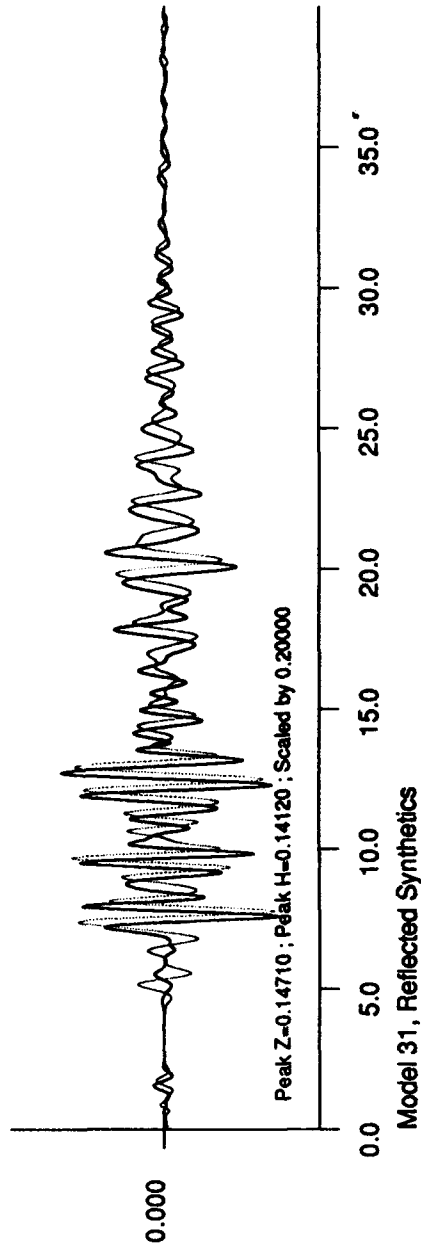
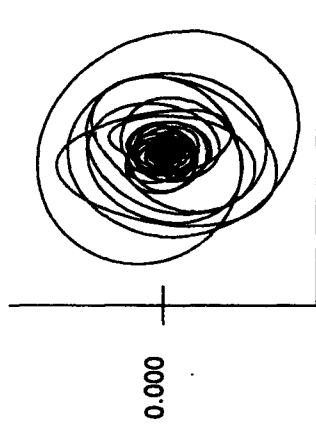
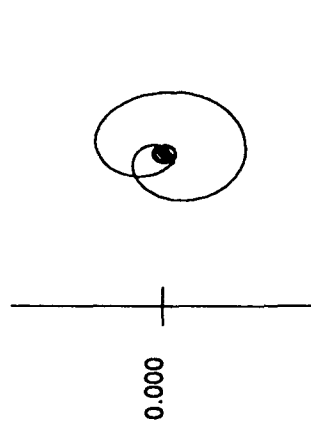


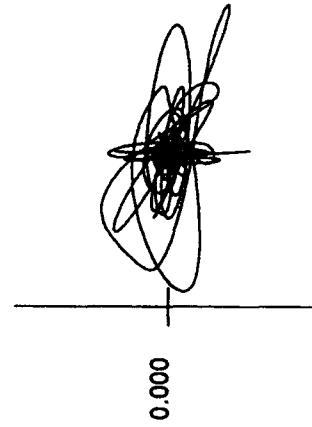
Figure 77



Particle Motion, Trace 2



Particle Motion, Trace 29



Particle Motion, Trace 59

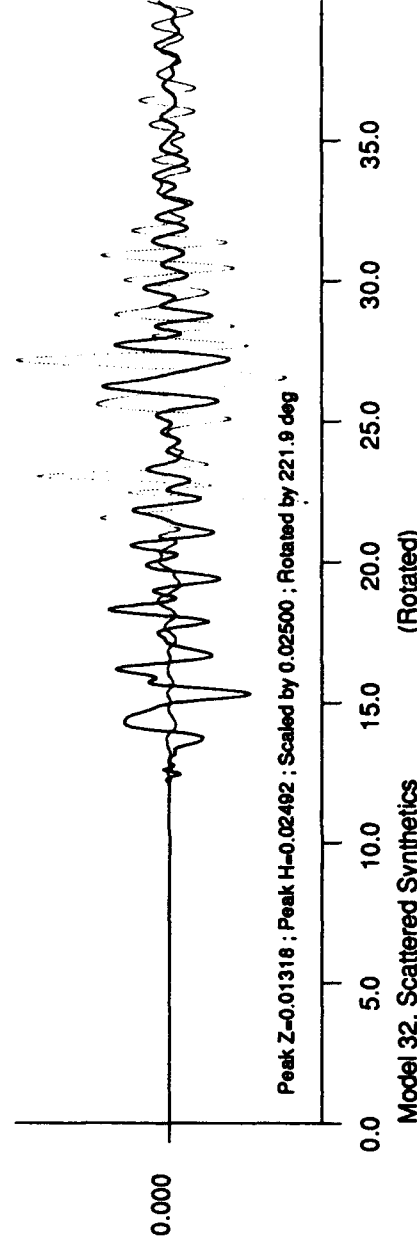
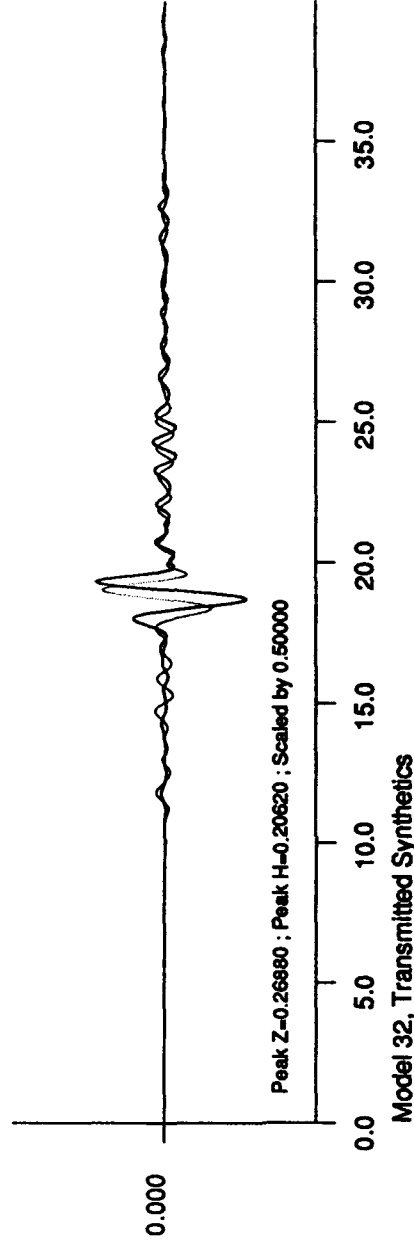
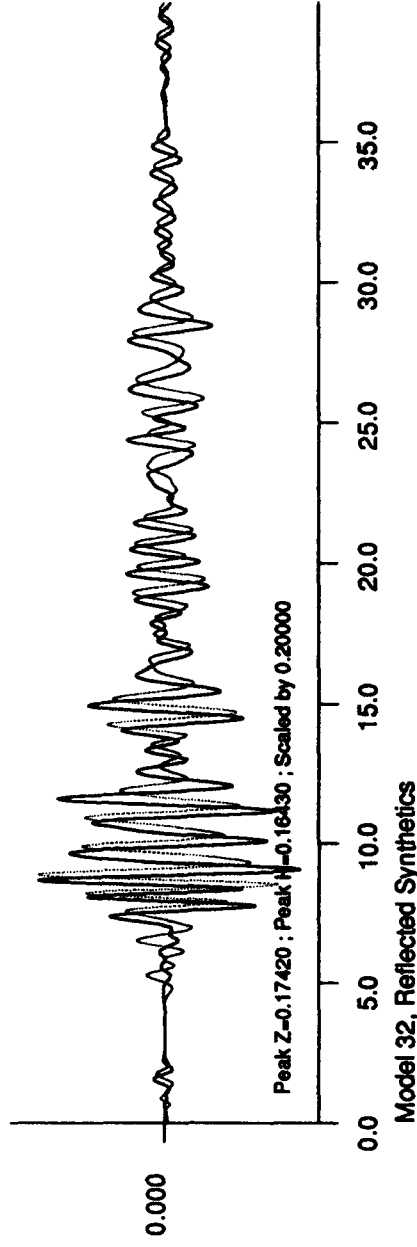
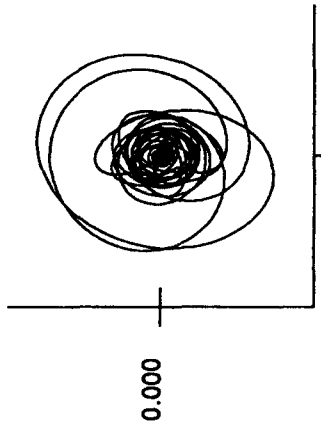
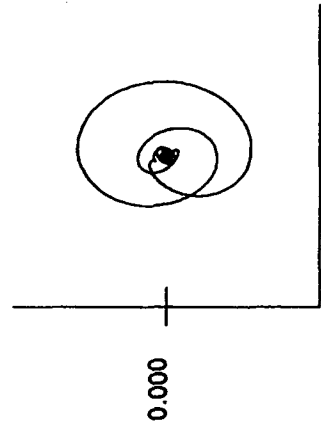
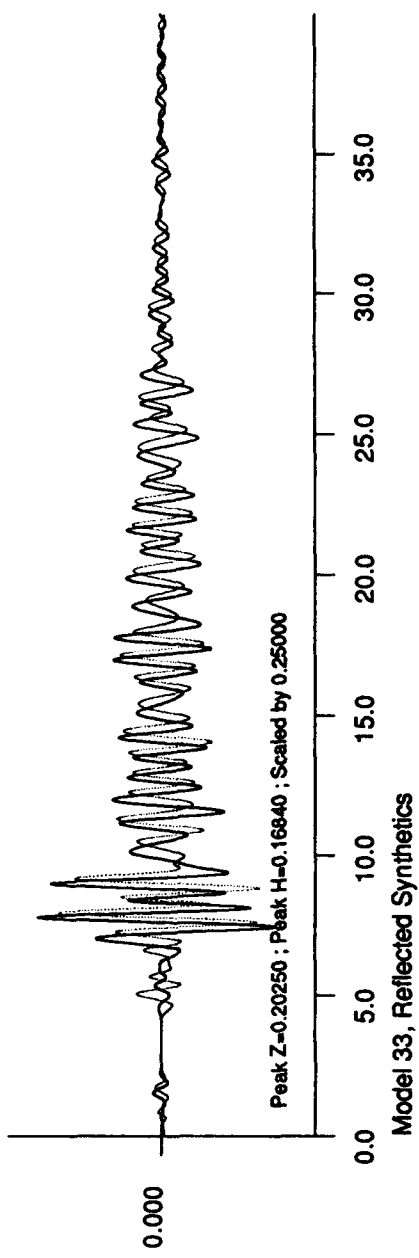


Figure 78

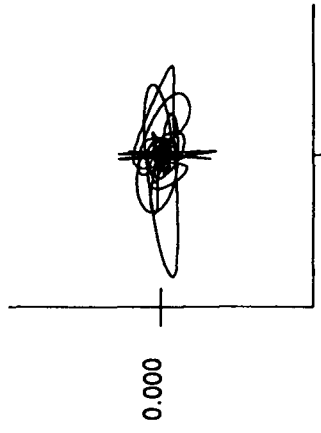
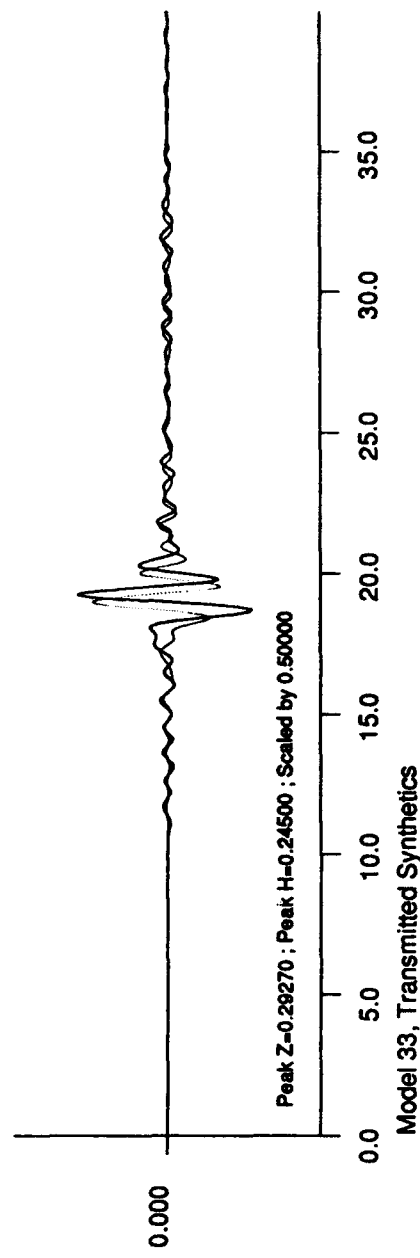
.. . . .



Particle Motion, Trace 2



Particle Motion, Trace 29



Particle Motion, Trace 59

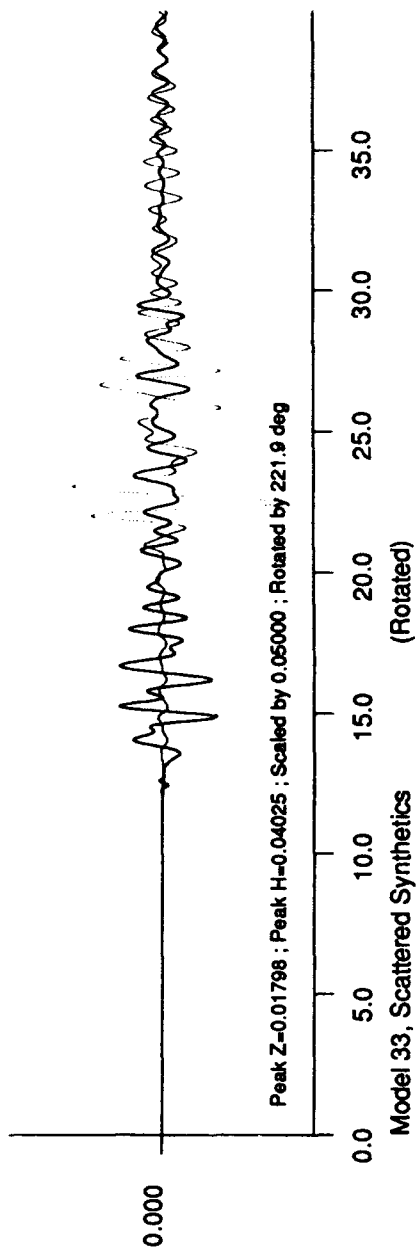
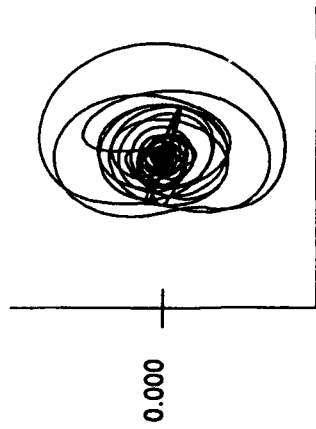
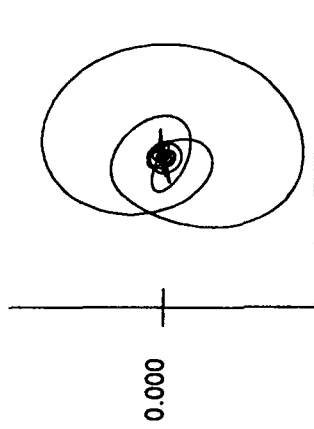


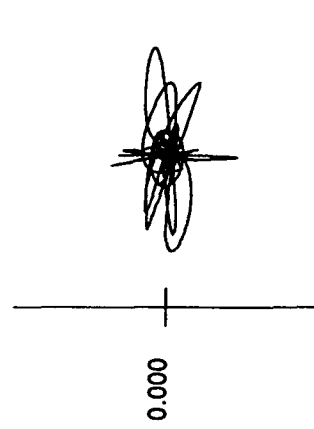
Figure 79



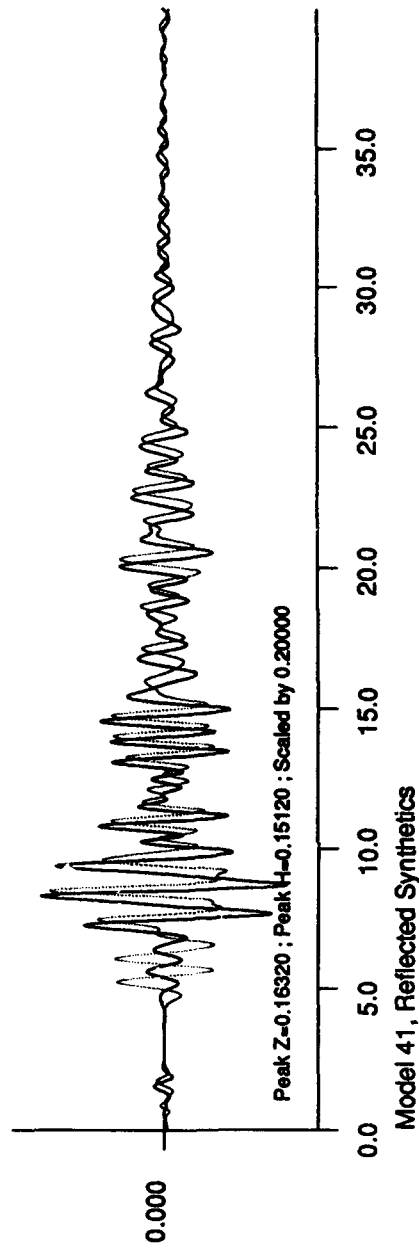
Particle Motion, Trace 2



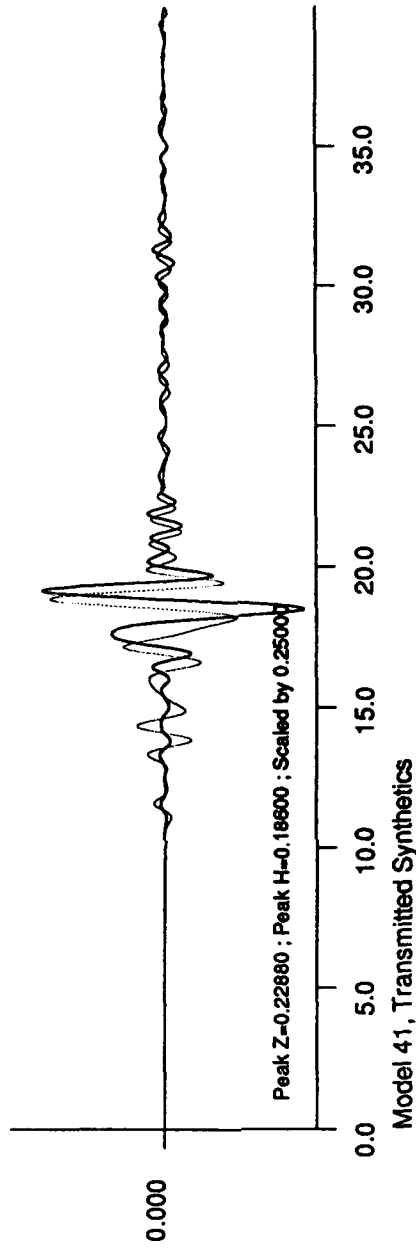
Particle Motion, Trace 29



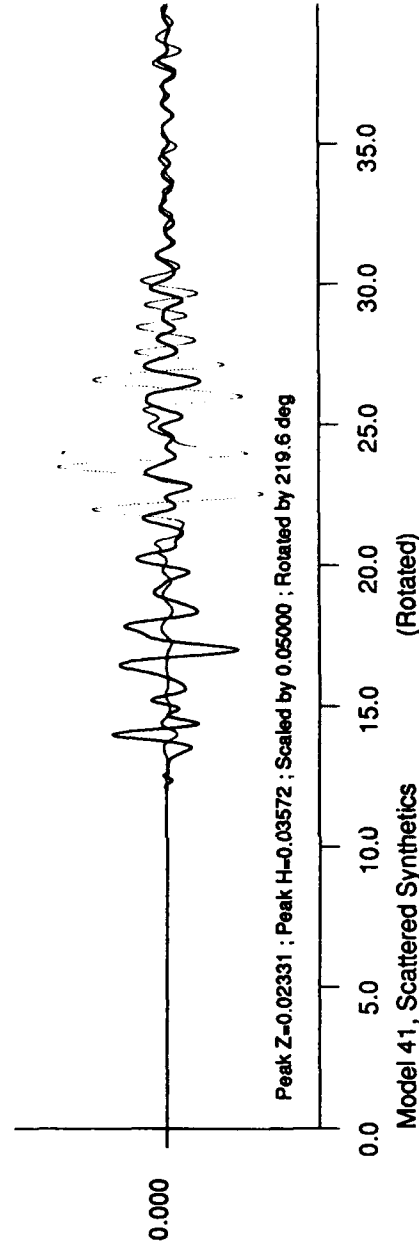
Particle Motion, Trace 59



Model 41, Reflected Synthetics



Model 41, Transmitted Synthetics

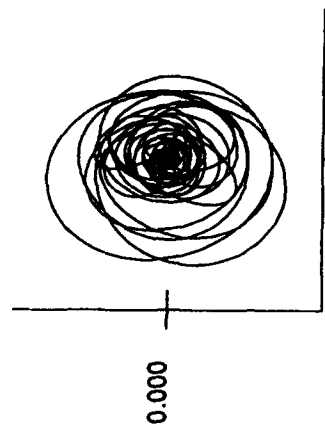


Model 41, Scattered Synthetics (Rotated)

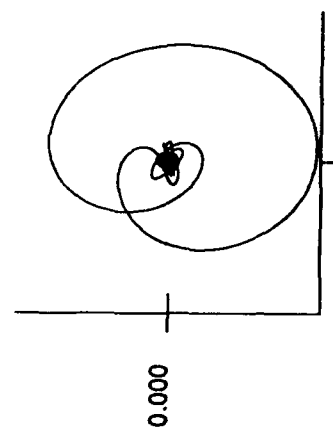
Figure 80

..

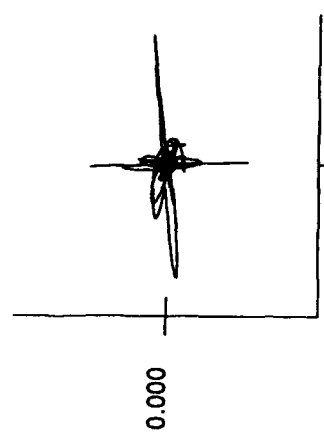
..



Particle Motion, Trace 2



Particle Motion, Trace 29



Particle Motion, Trace 59

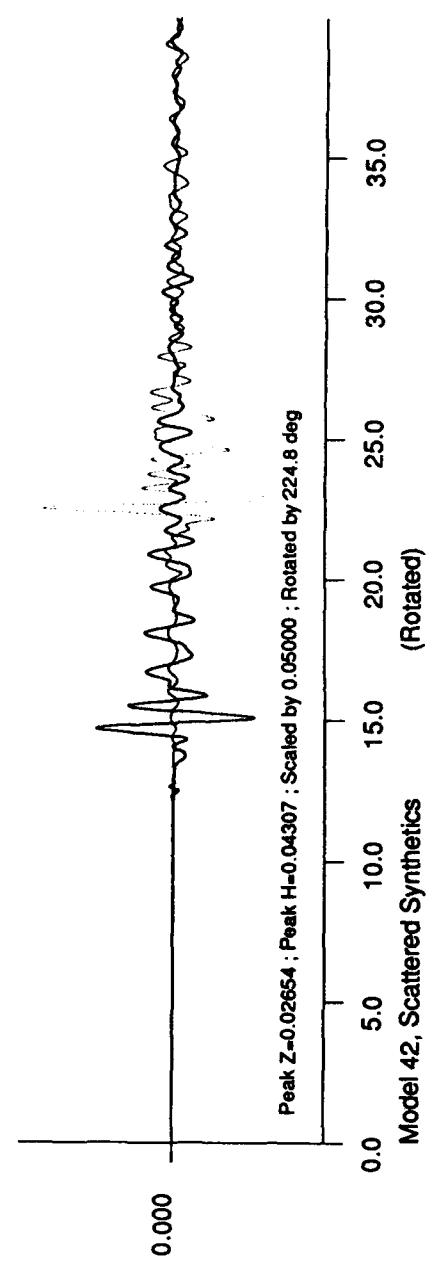
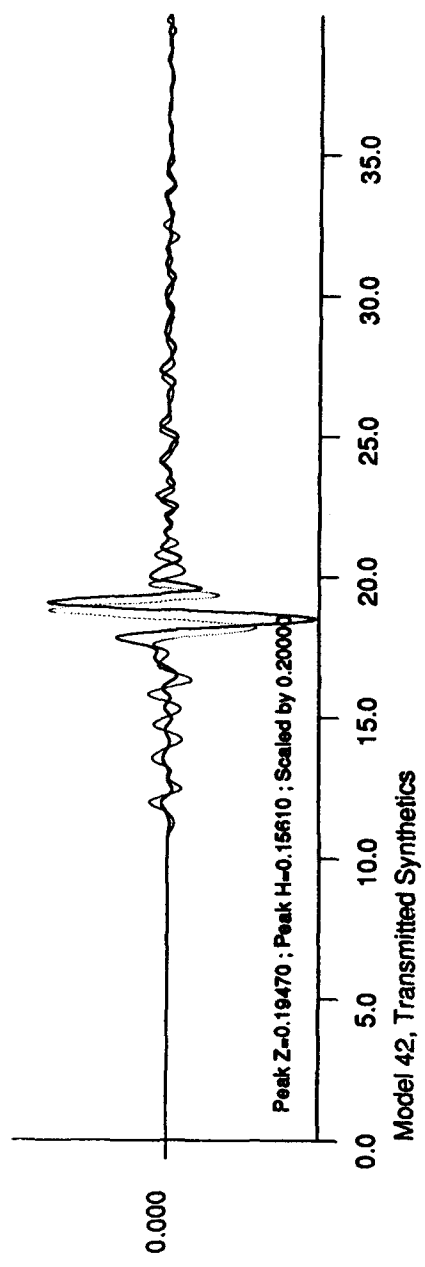
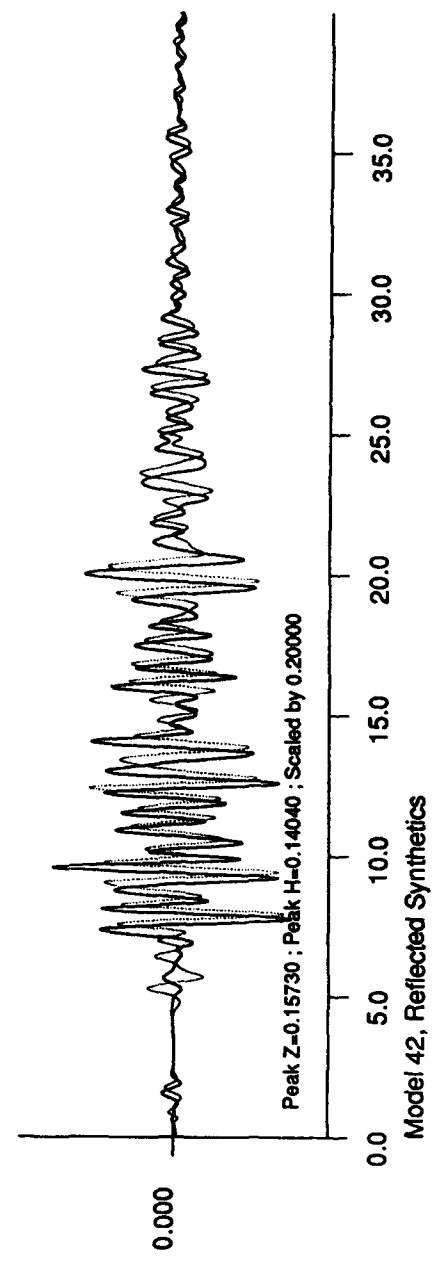


Figure 81

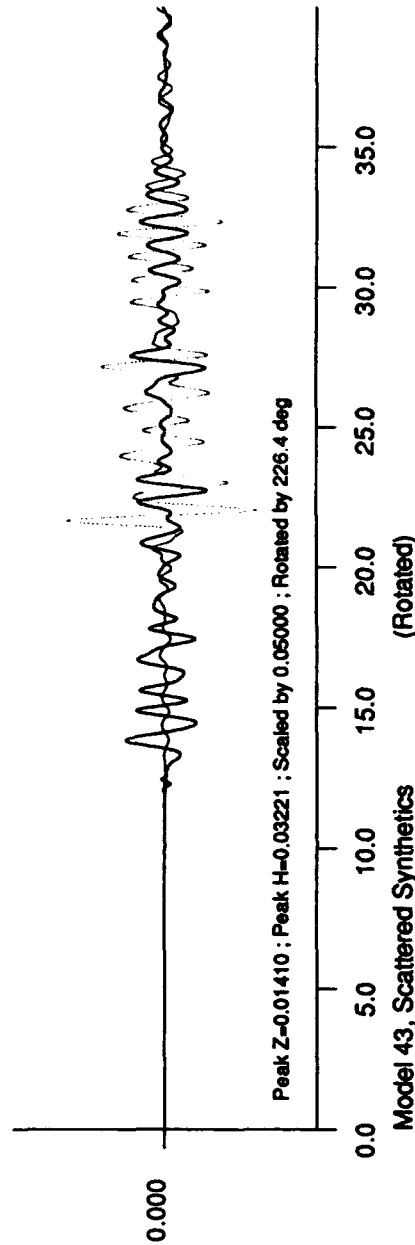
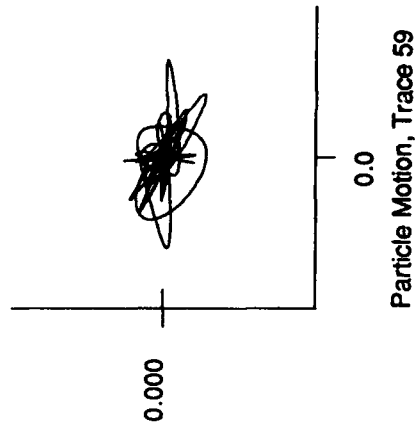
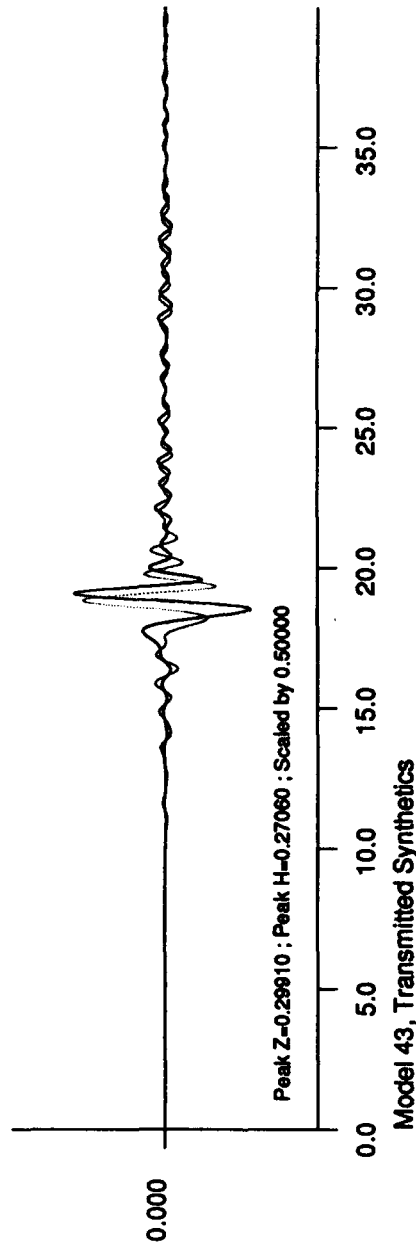
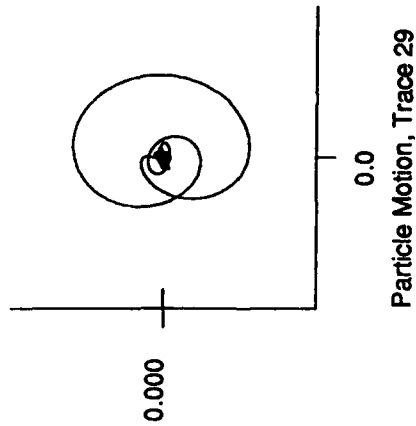
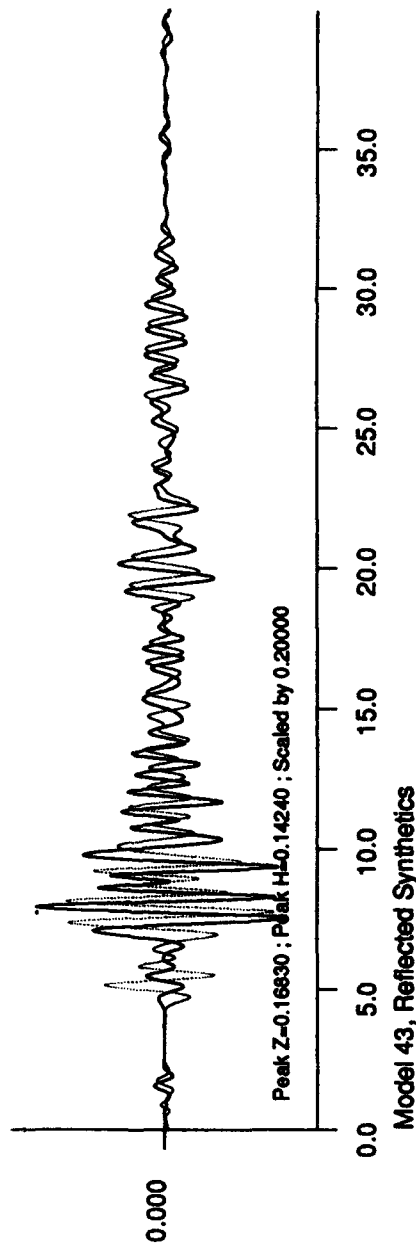
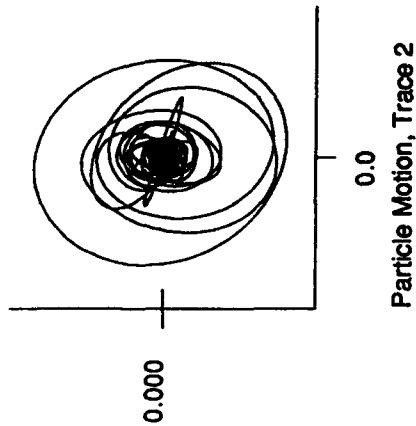


Figure 82

.. . . .

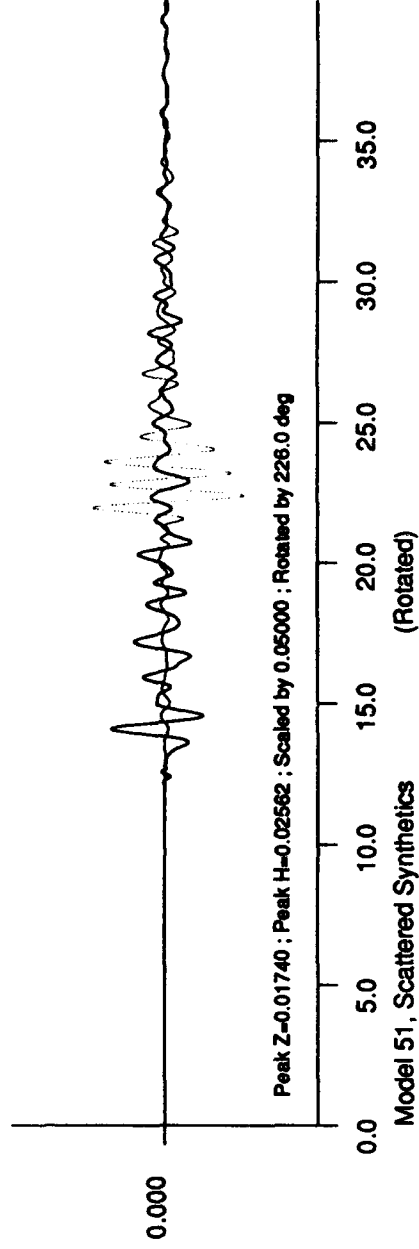
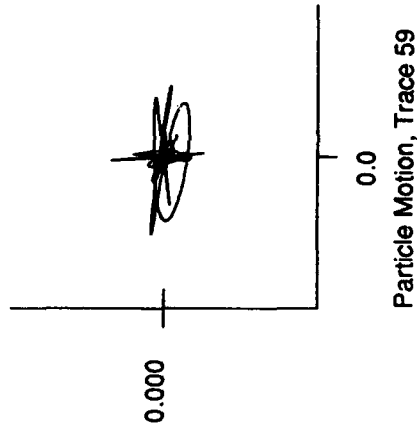
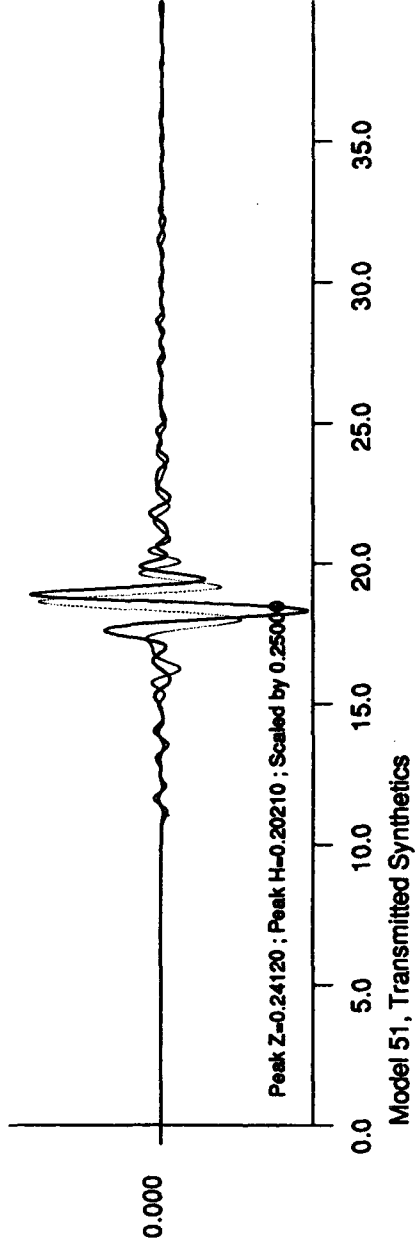
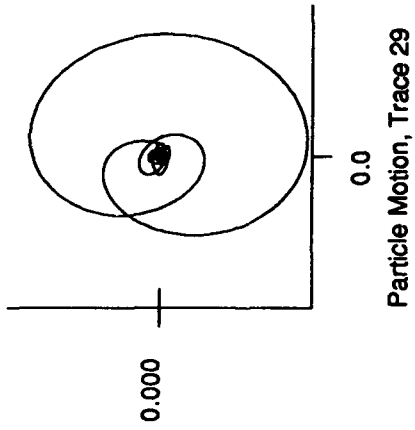
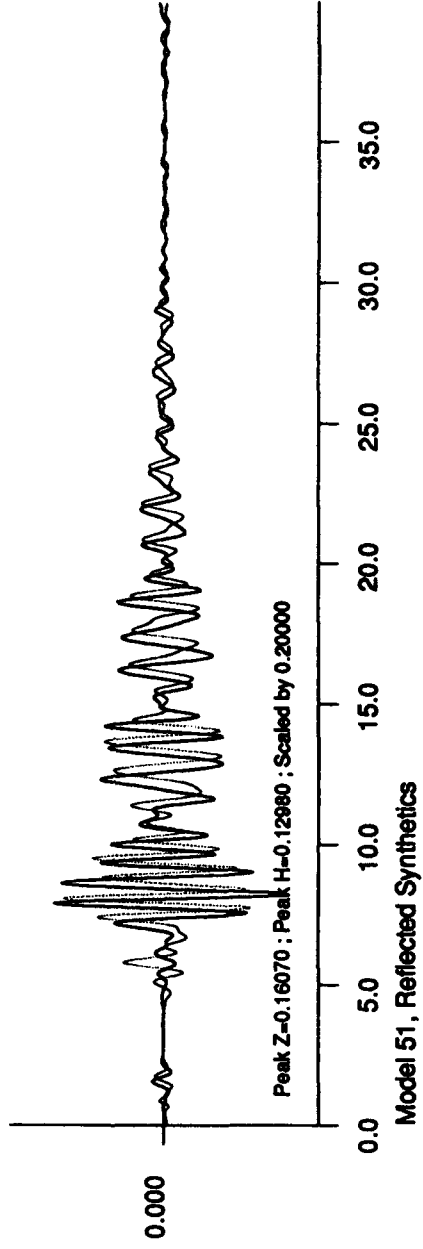
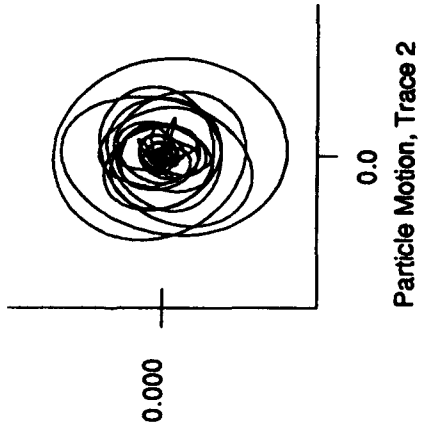


Figure 83

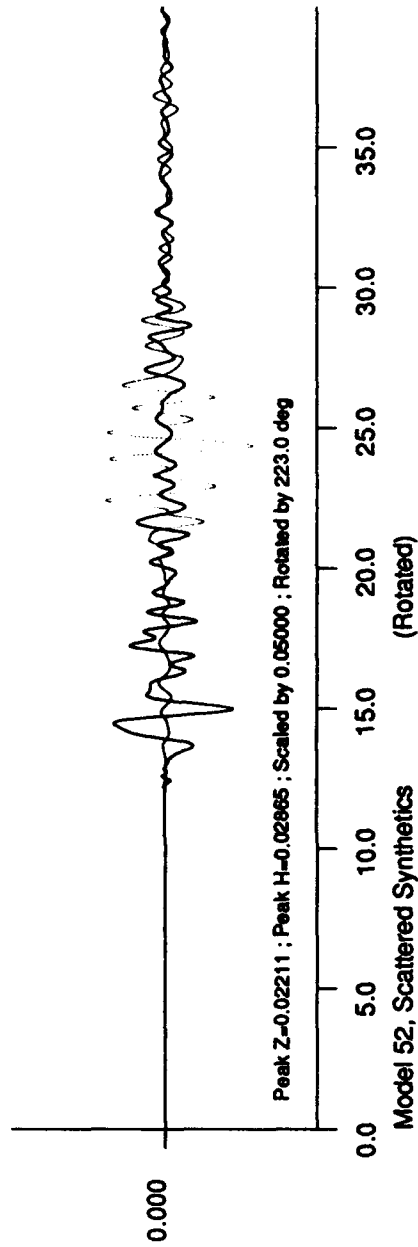
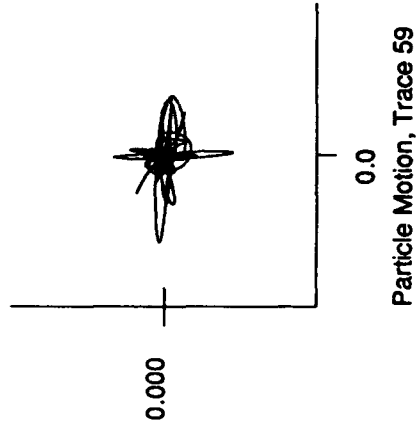
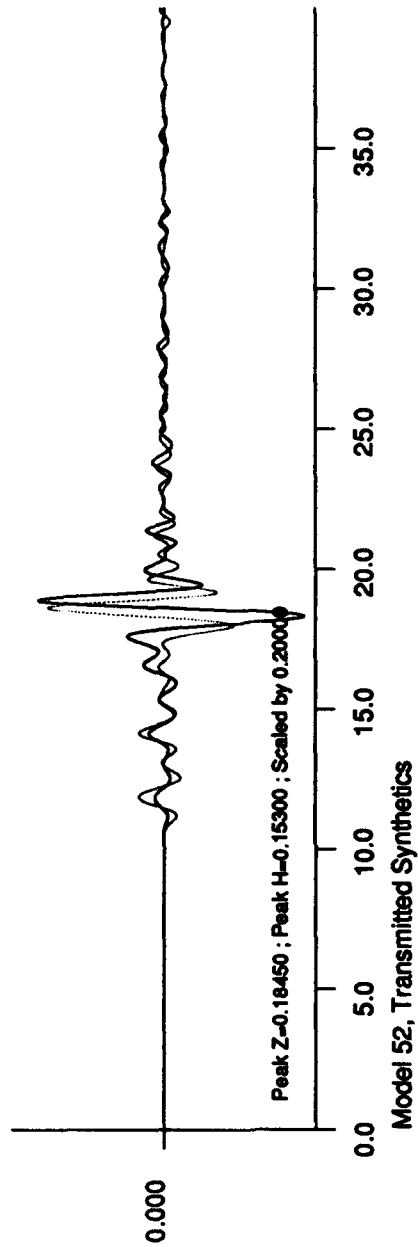
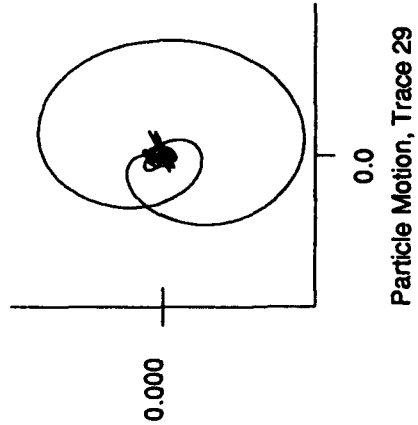
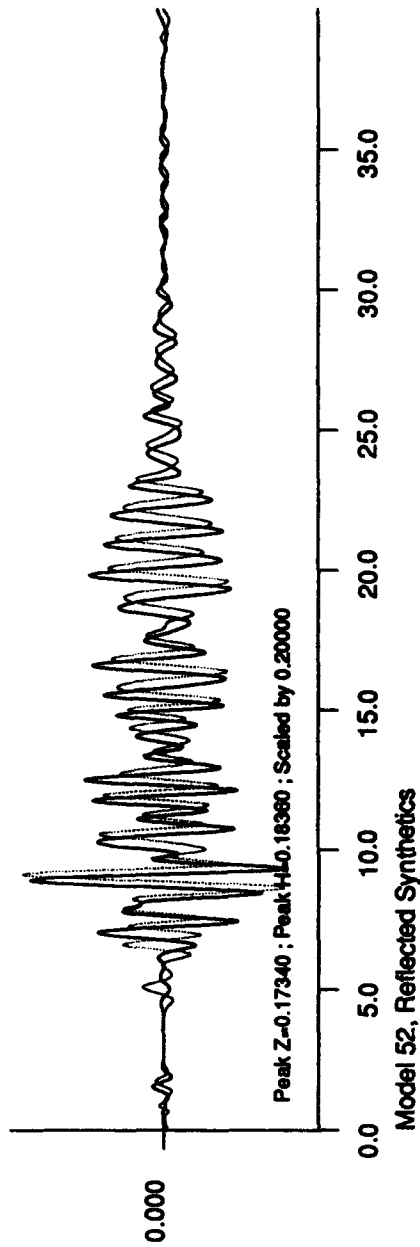
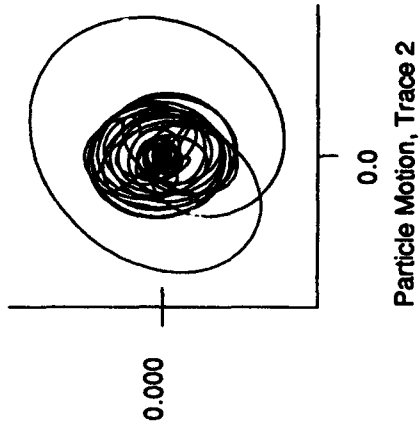
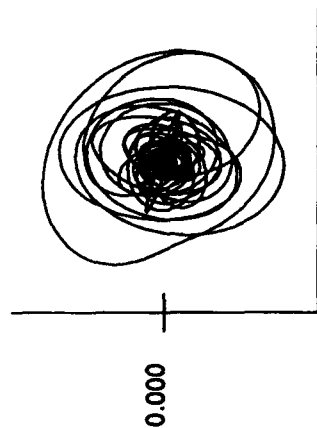


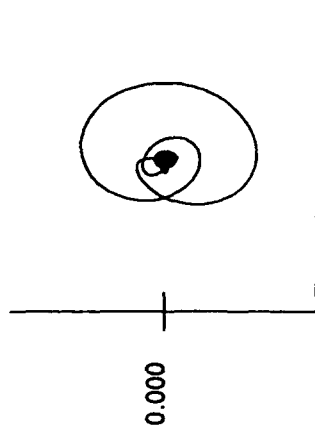
Figure 84

.. . .

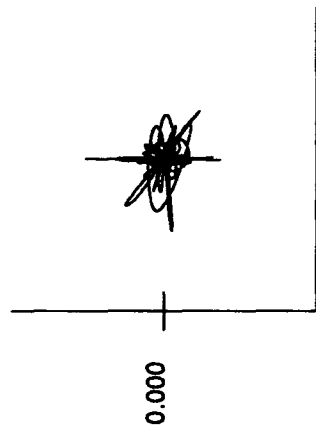
.. . .



Particle Motion, Trace 2



Particle Motion, Trace 29



Particle Motion, Trace 59

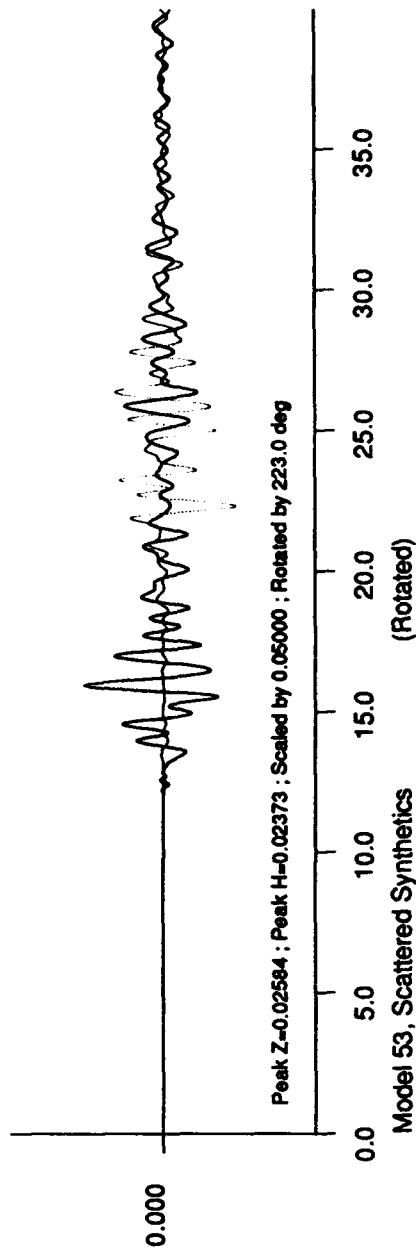
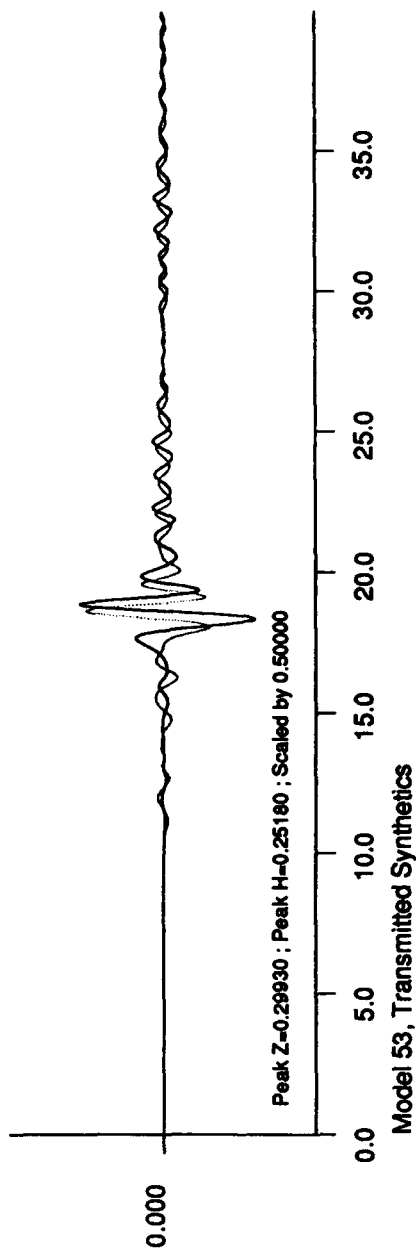
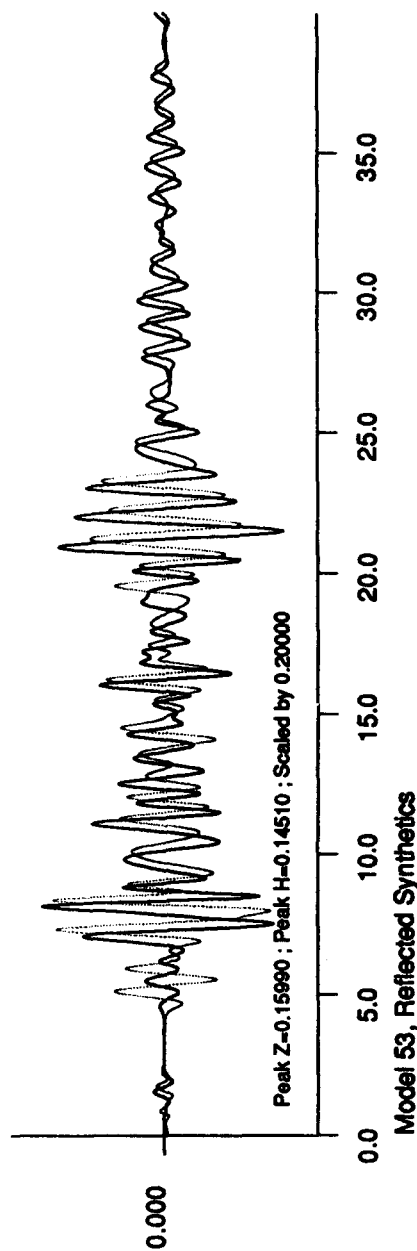
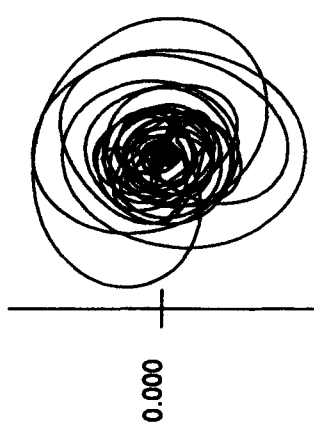
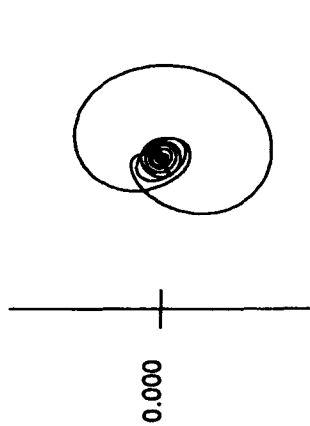


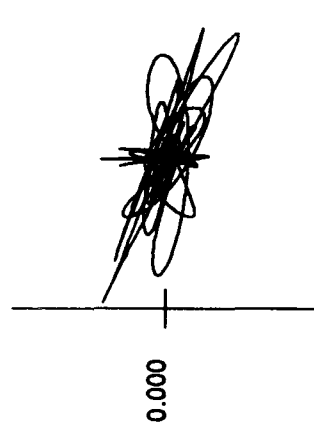
Figure 85



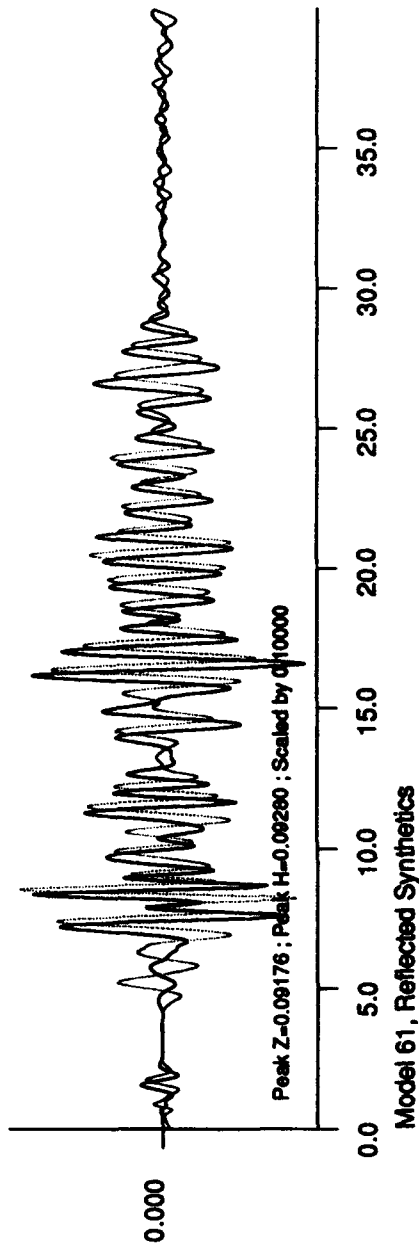
Particle Motion, Trace 2



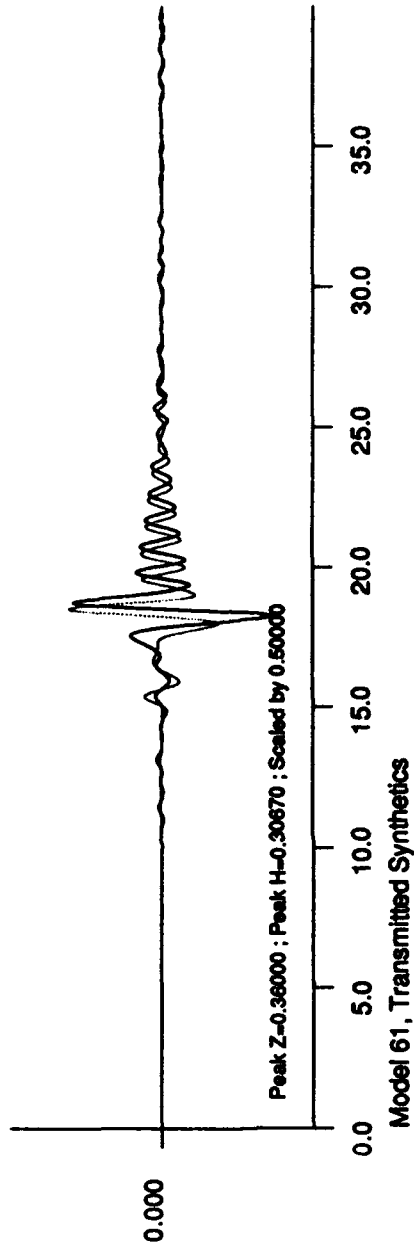
Particle Motion, Trace 29



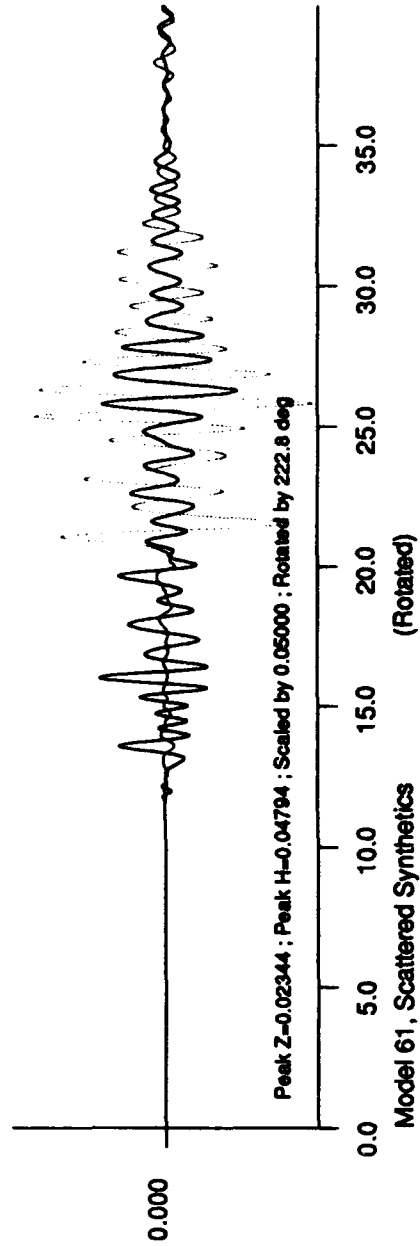
Particle Motion, Trace 59



Model 61, Reflected Synthetics



Model 61, Transmitted Synthetics



Model 61, Scattered Synthetics
(Rotated)

Figure 86

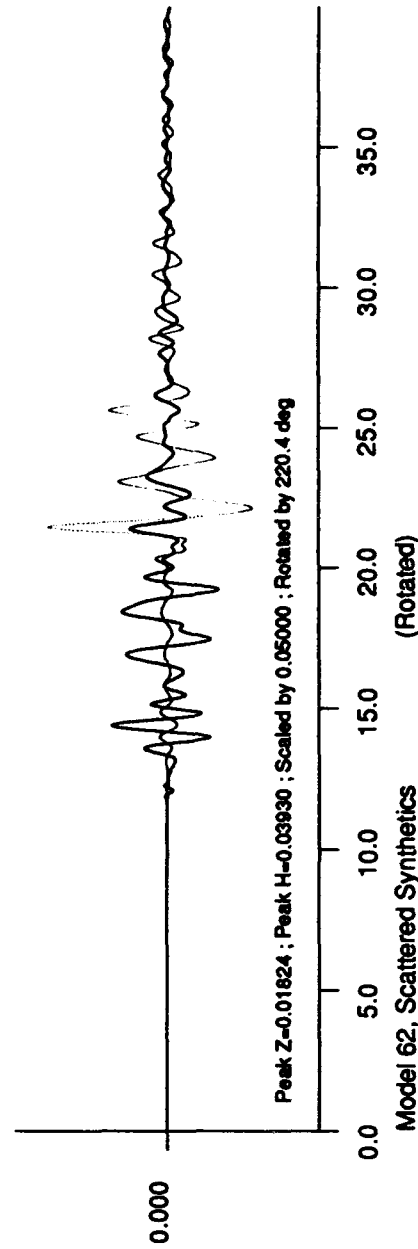
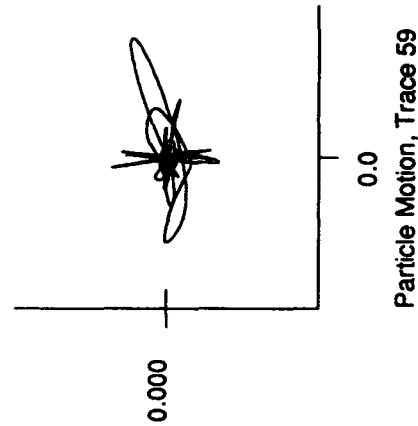
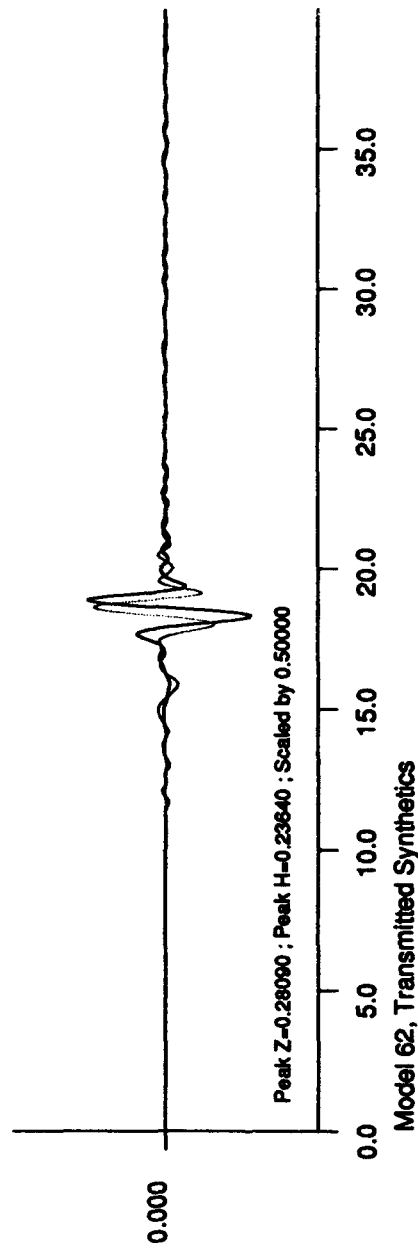
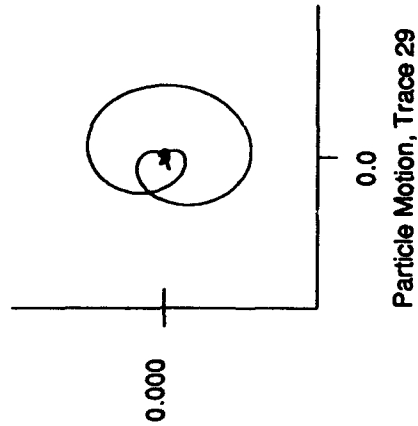
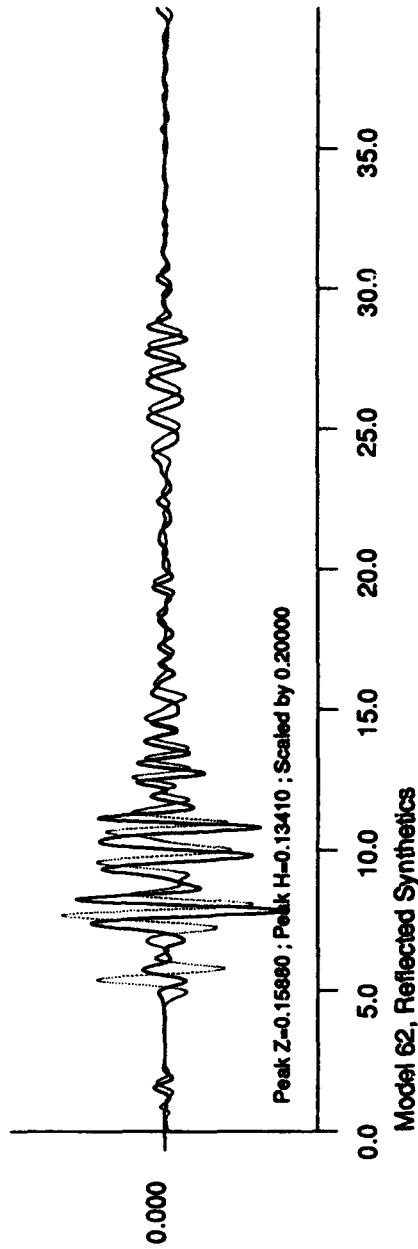
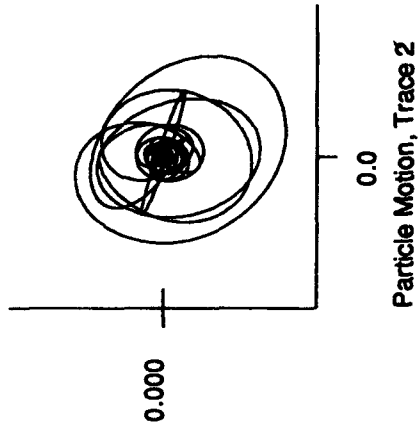


Figure 87

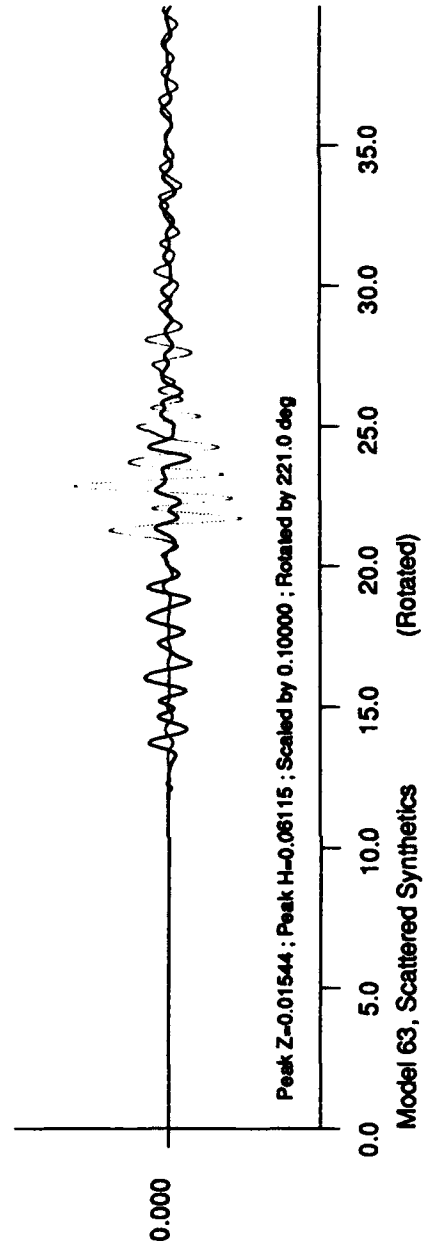
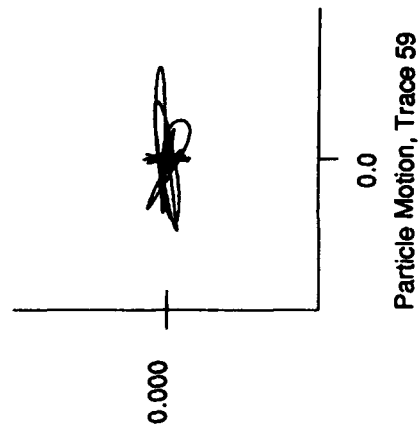
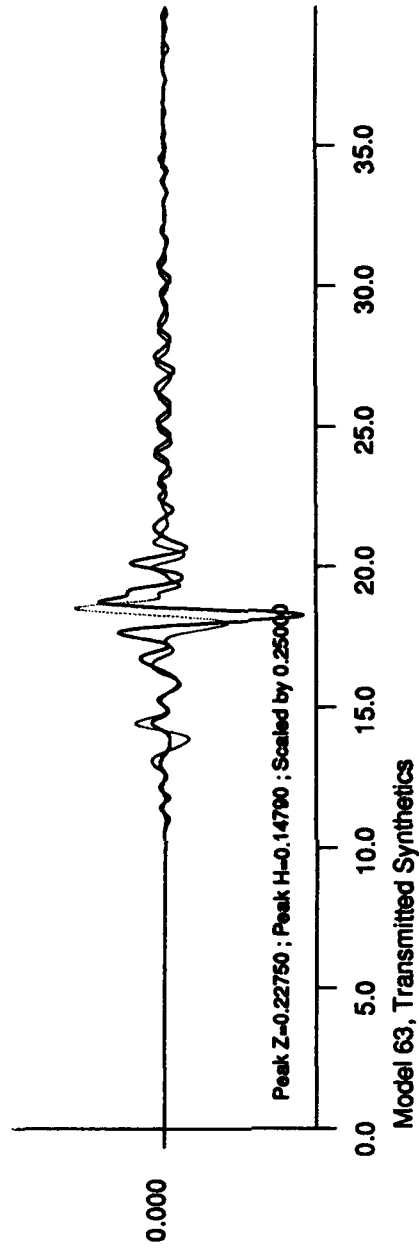
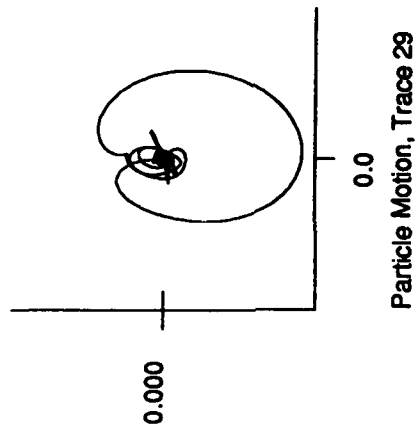
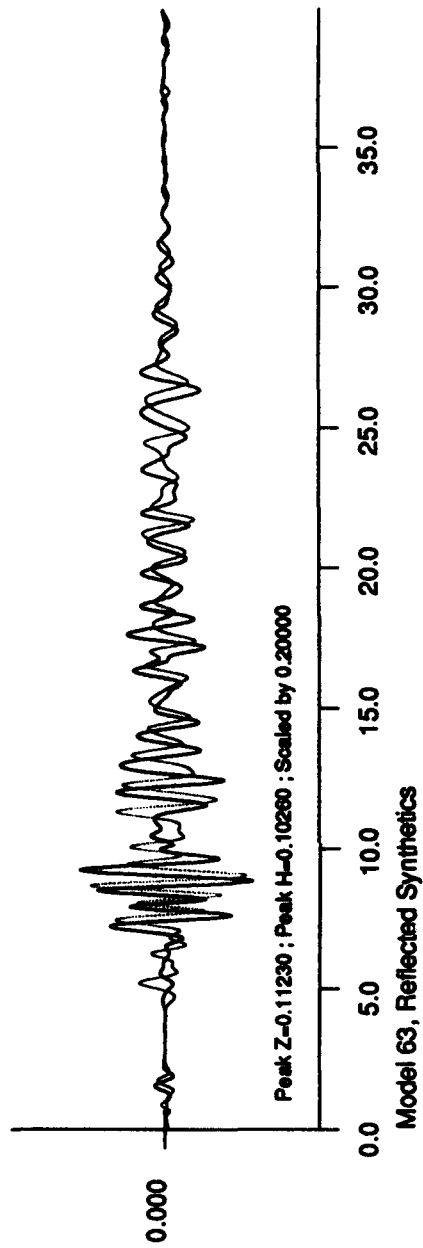
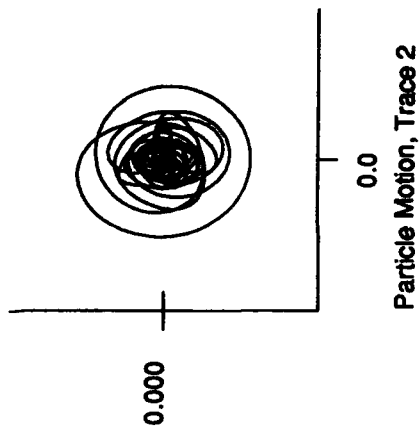
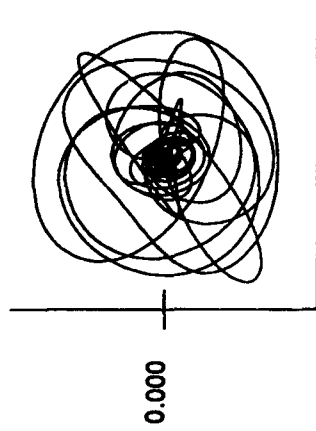
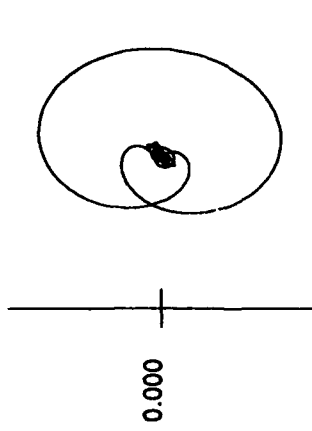


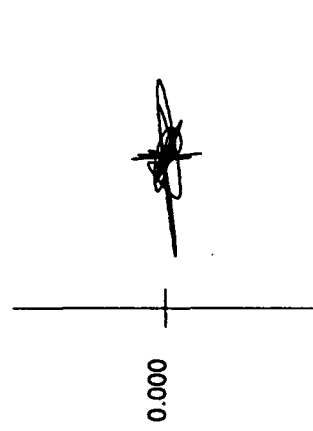
Figure 88



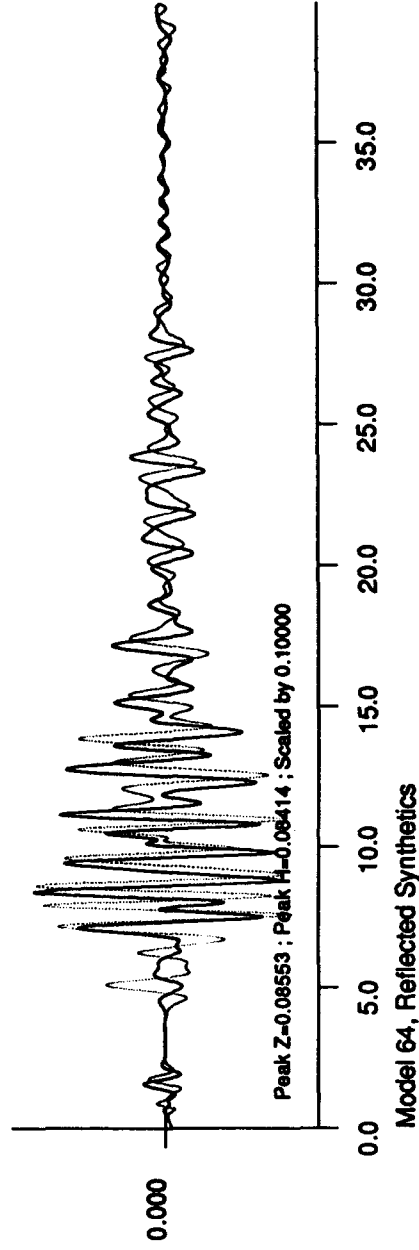
Particle Motion, Trace 2



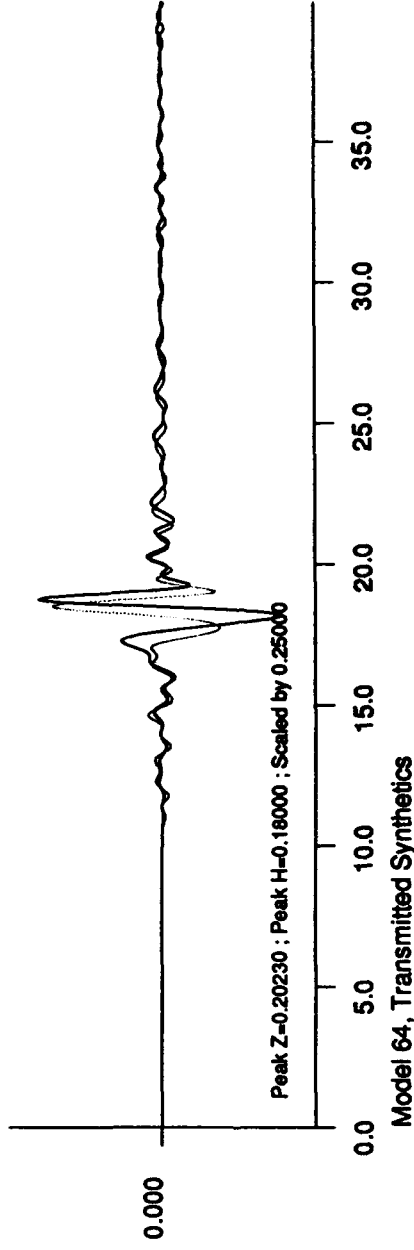
Particle Motion, Trace 29



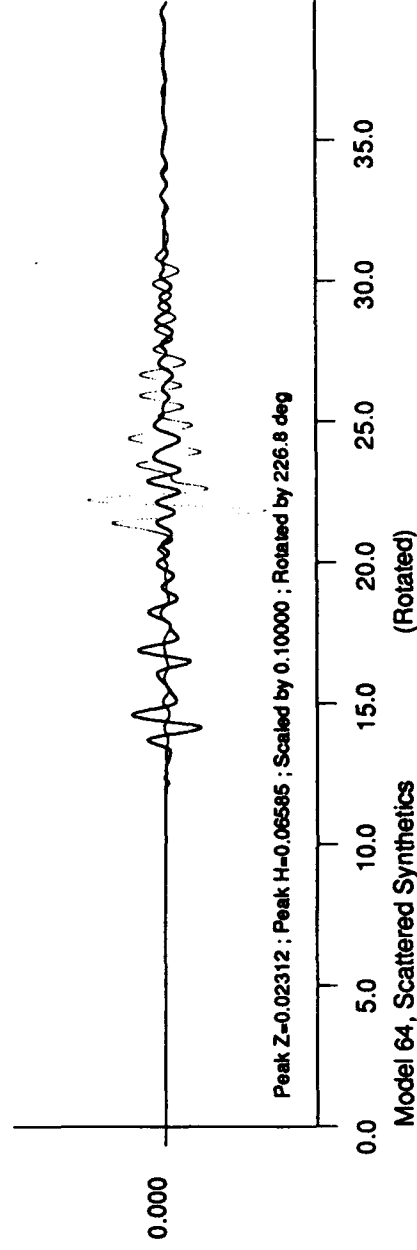
Particle Motion, Trace 59



Model 64, Reflected Synthetics



Model 64, Transmitted Synthetics



Model 64, Scattered Synthetics (Rotated)

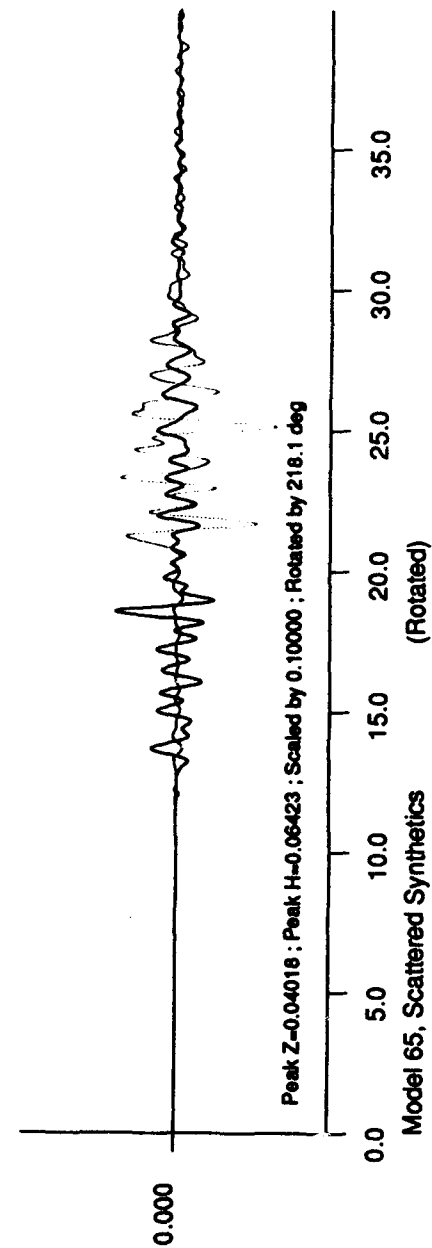
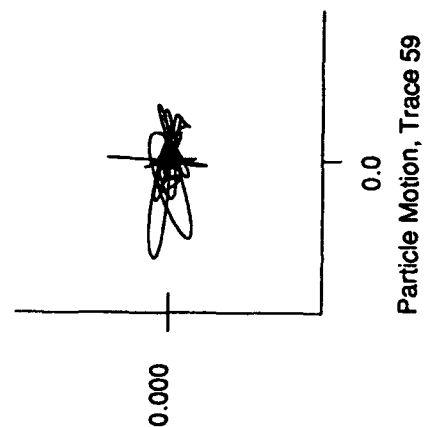
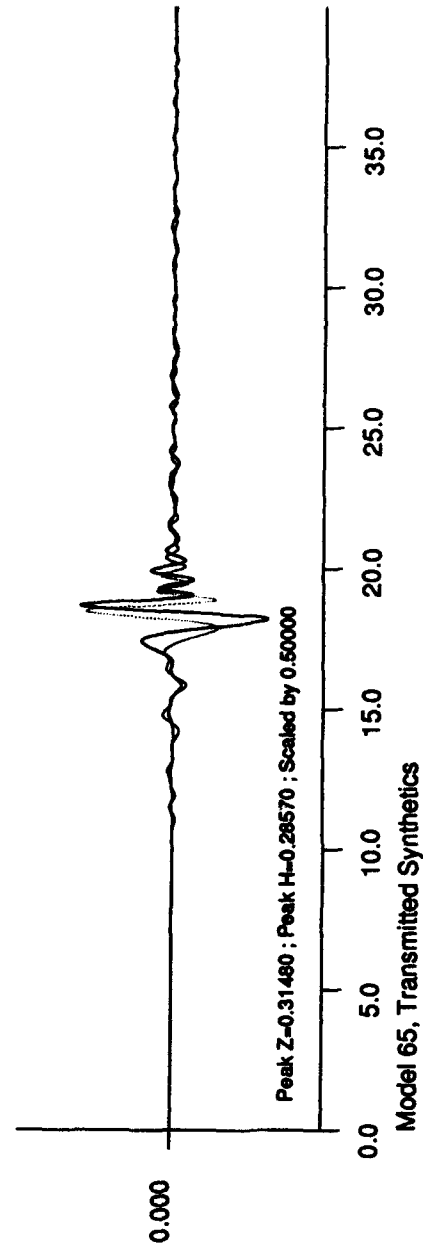
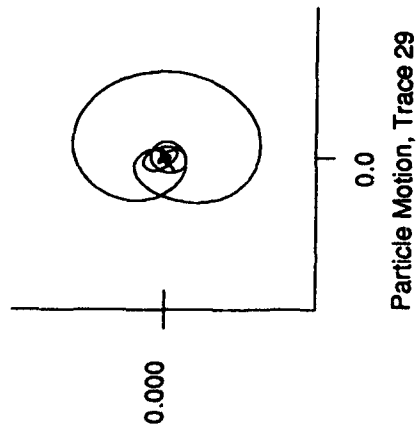
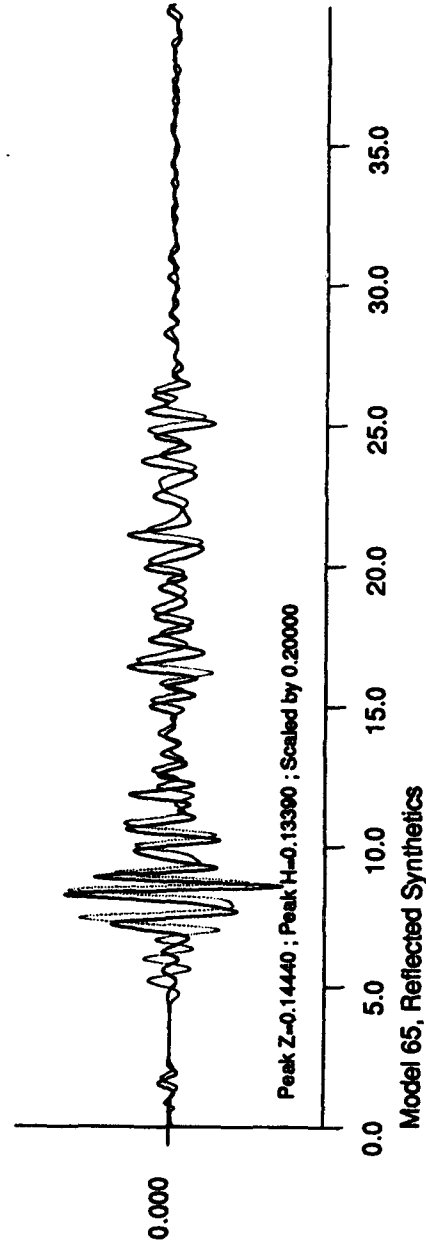
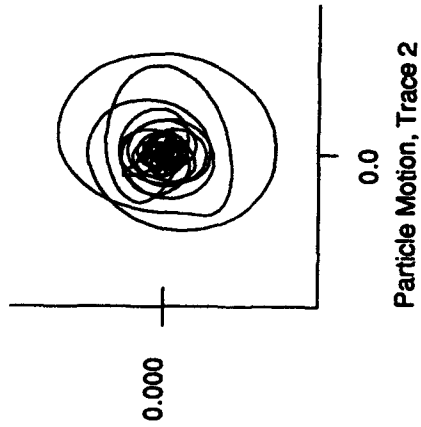
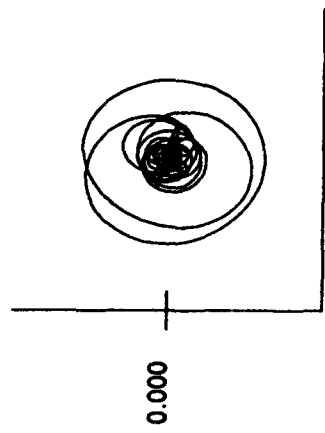
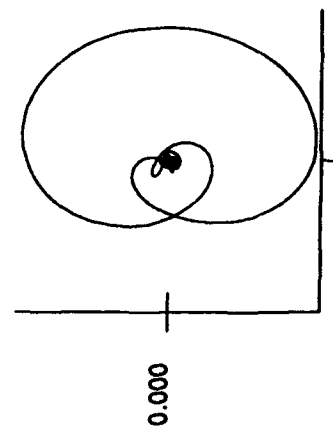


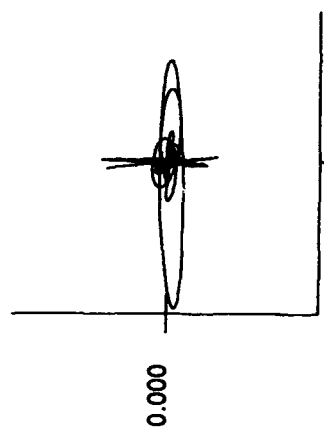
Figure 90



Particle Motion, Trace 2



Particle Motion, Trace 29



Particle Motion, Trace 59

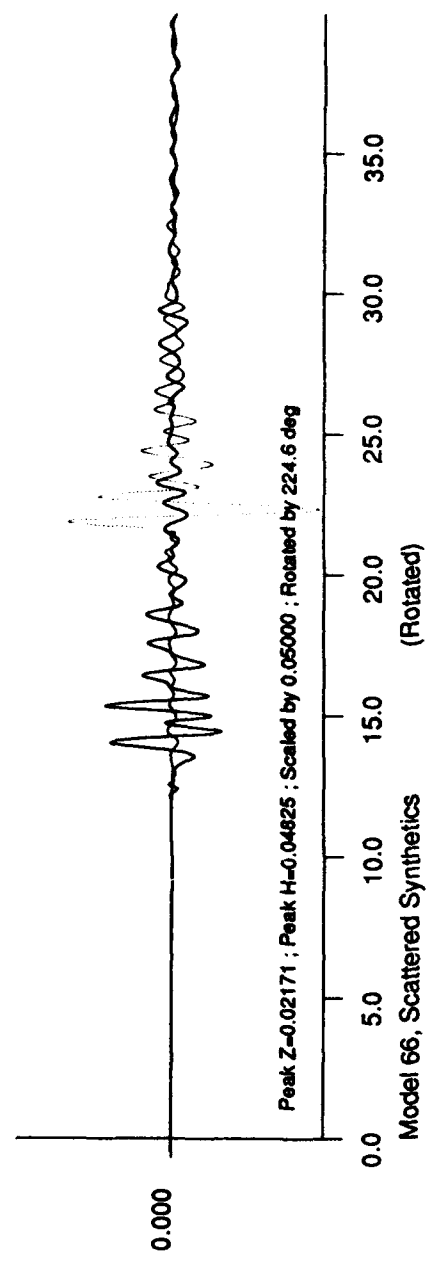
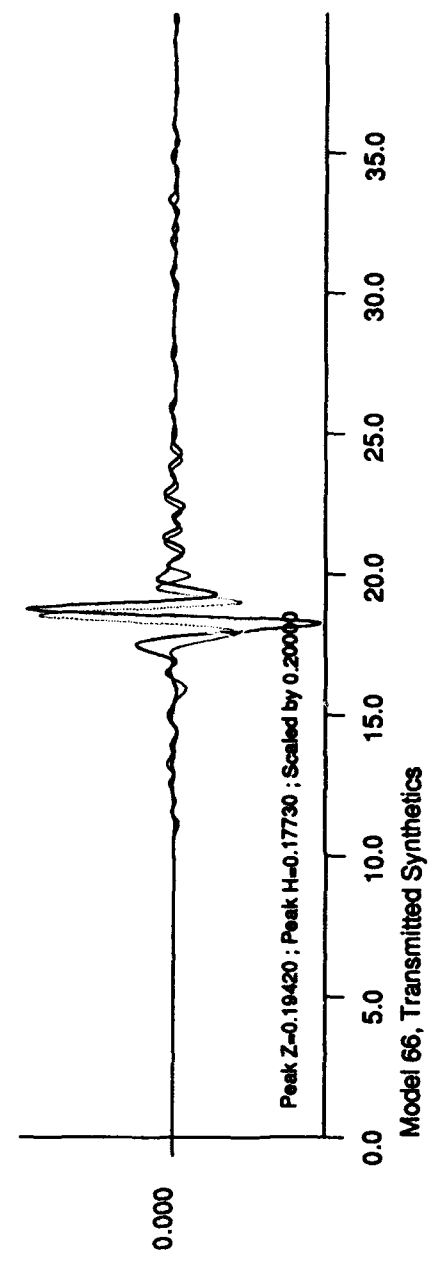
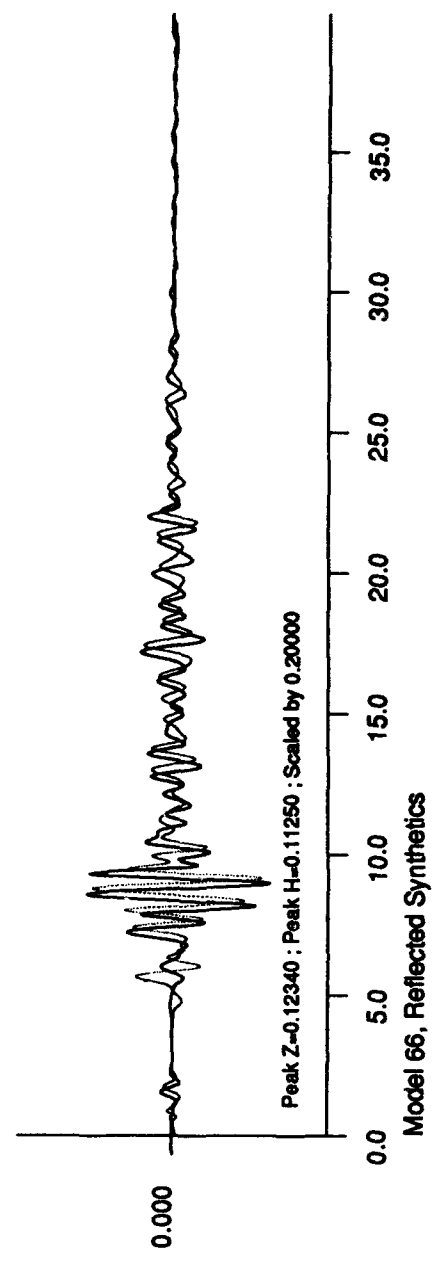


Figure 91

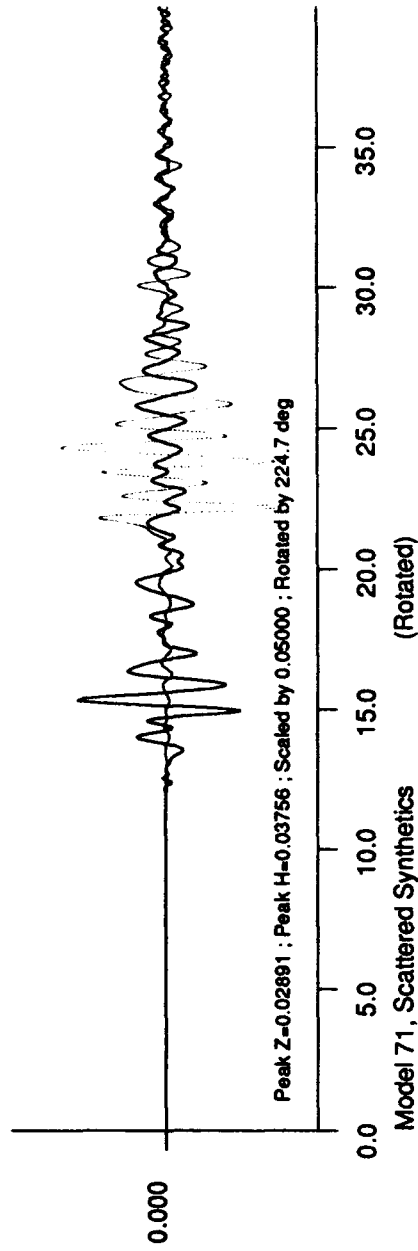
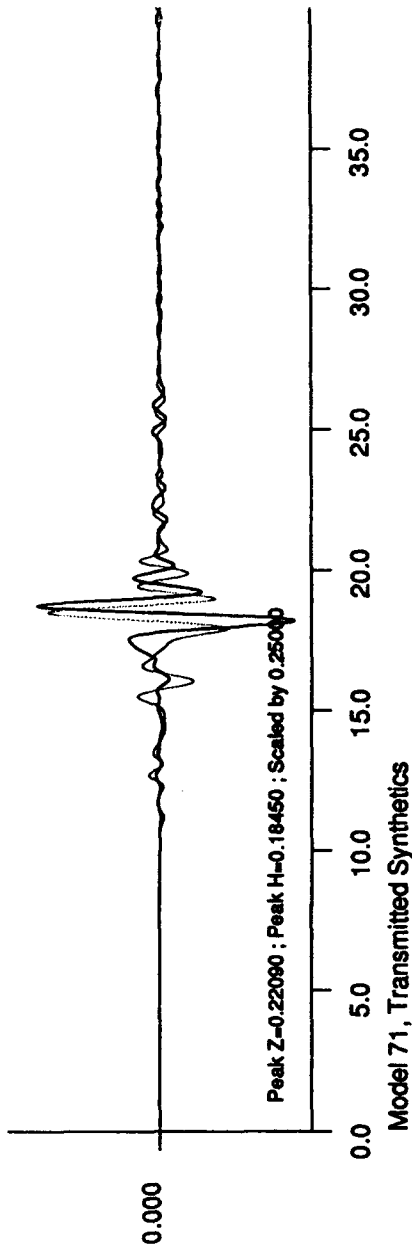
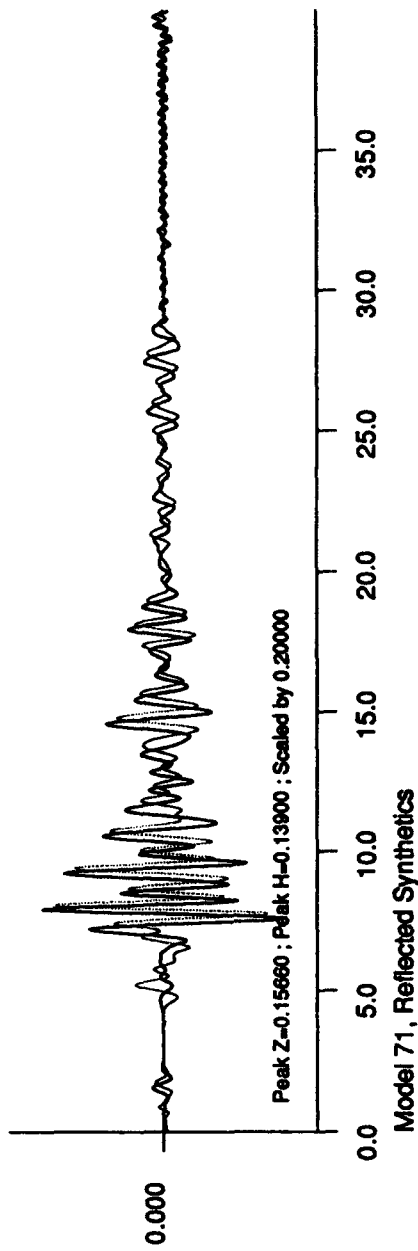
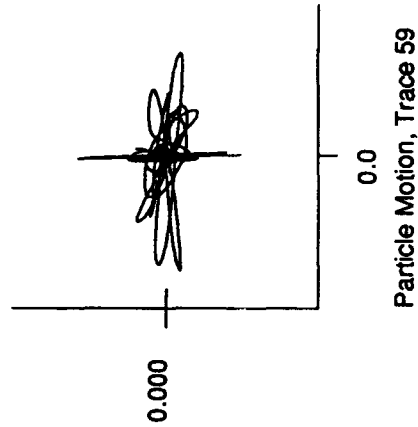
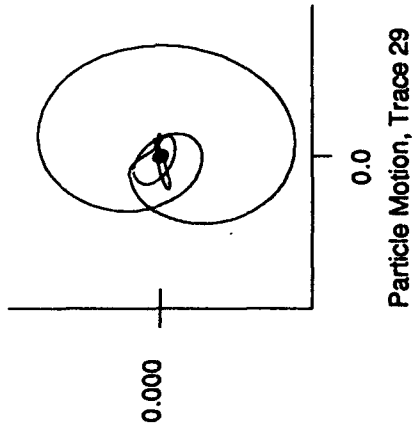
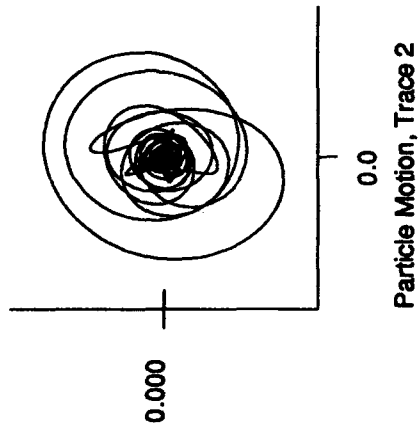
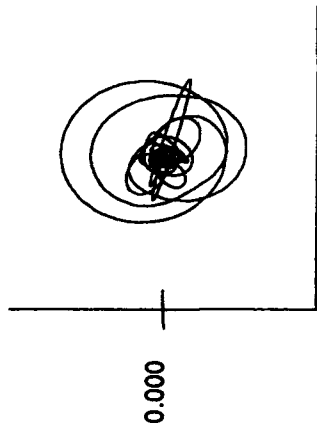
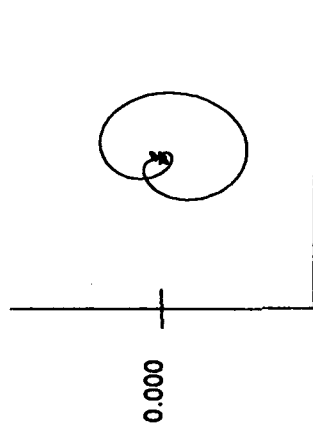


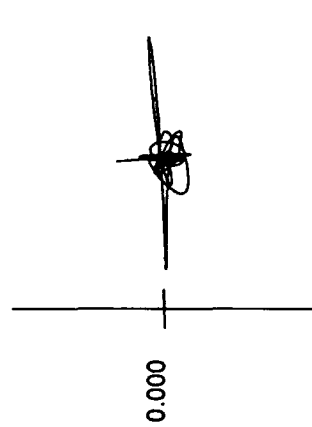
Figure 92



Particle Motion, Trace 2



Particle Motion, Trace 29



Particle Motion, Trace 59

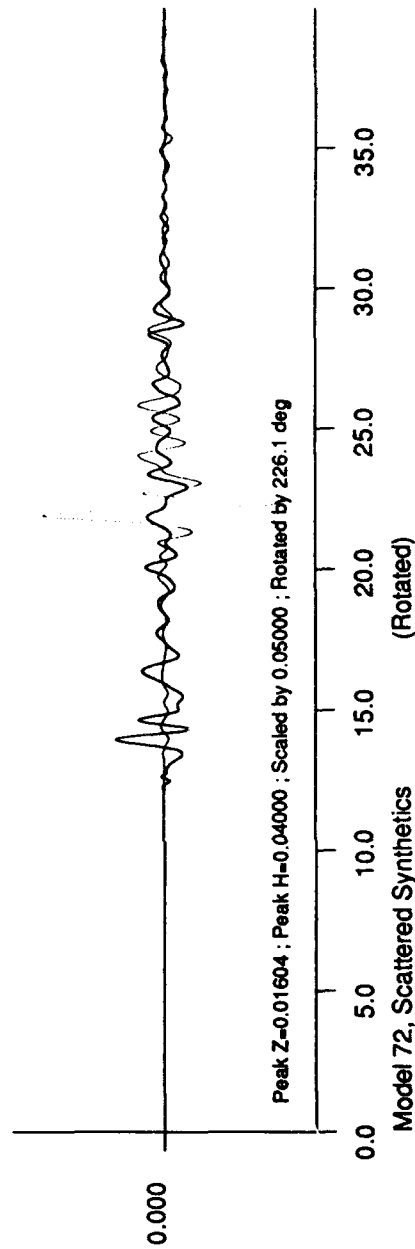
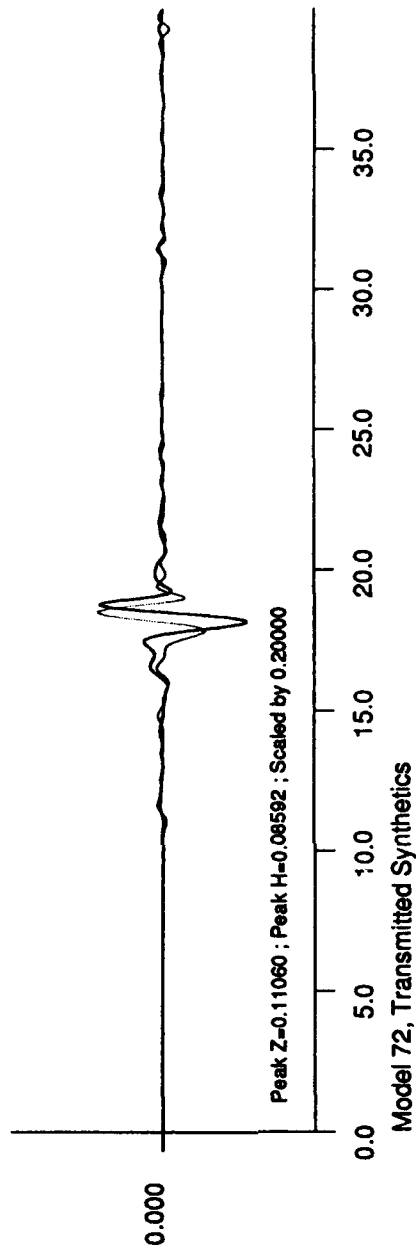
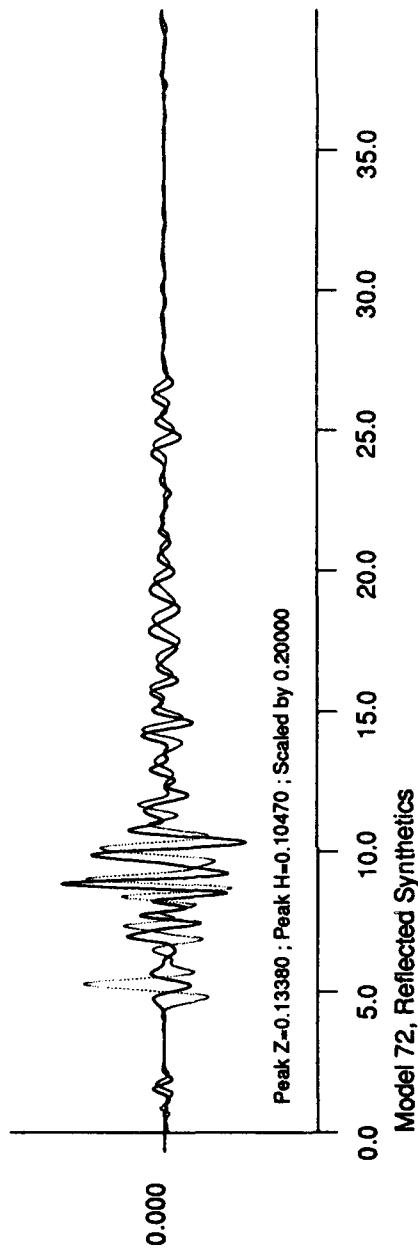
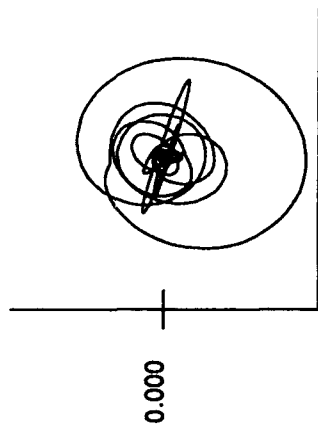
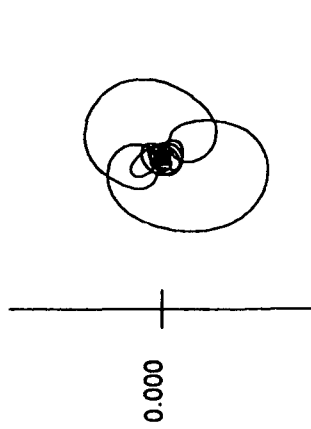


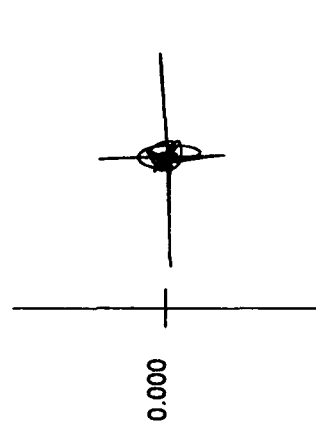
Figure 93



Particle Motion, Trace 2



Particle Motion, Trace 29



Particle Motion, Trace 59

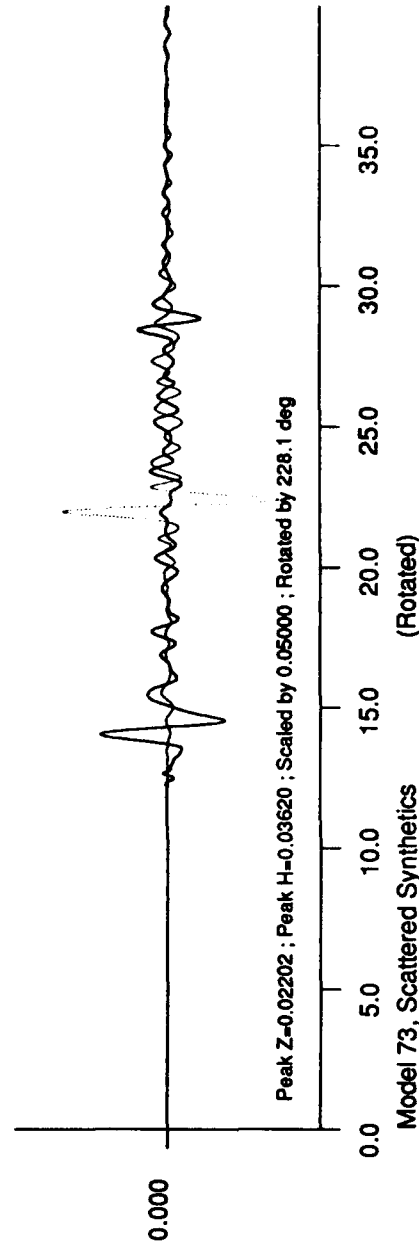
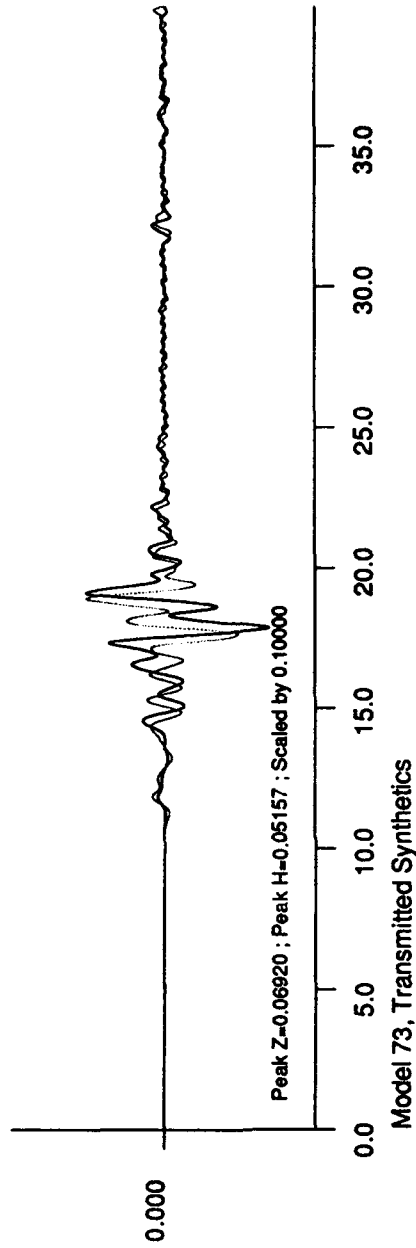
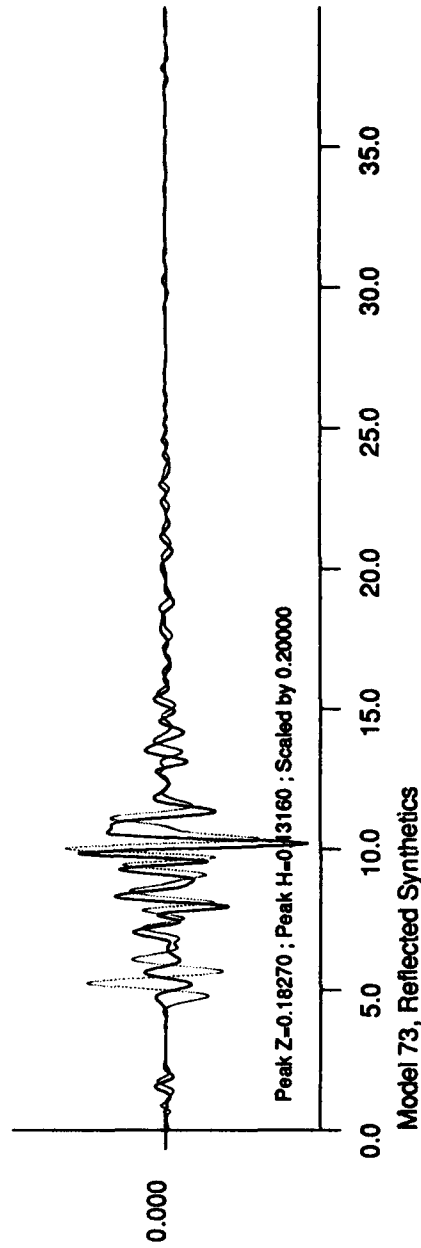
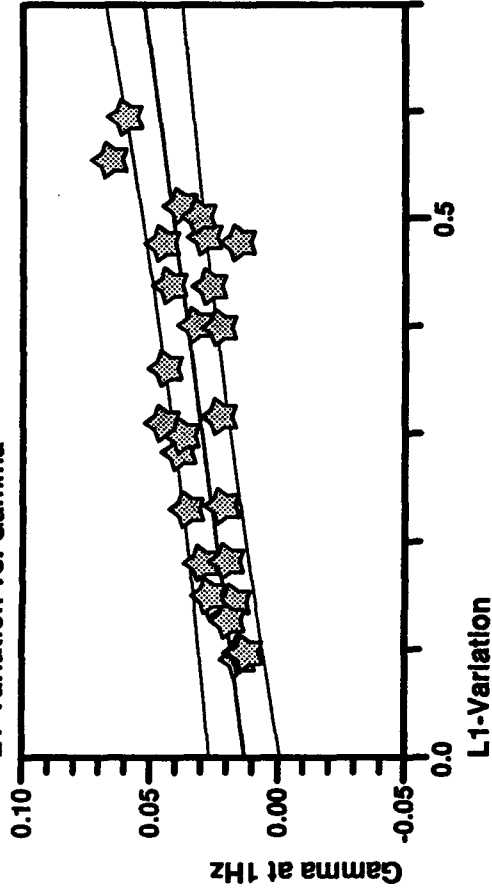


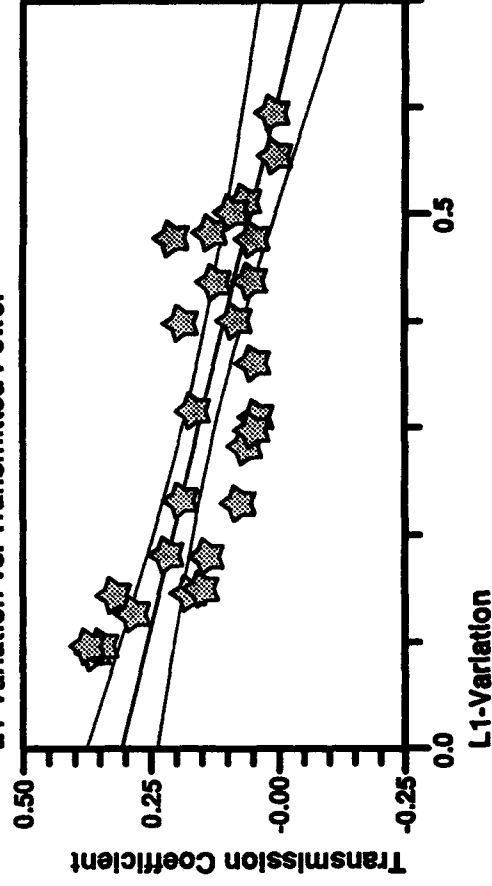
Figure 94

L1-Variation vs. Gamma



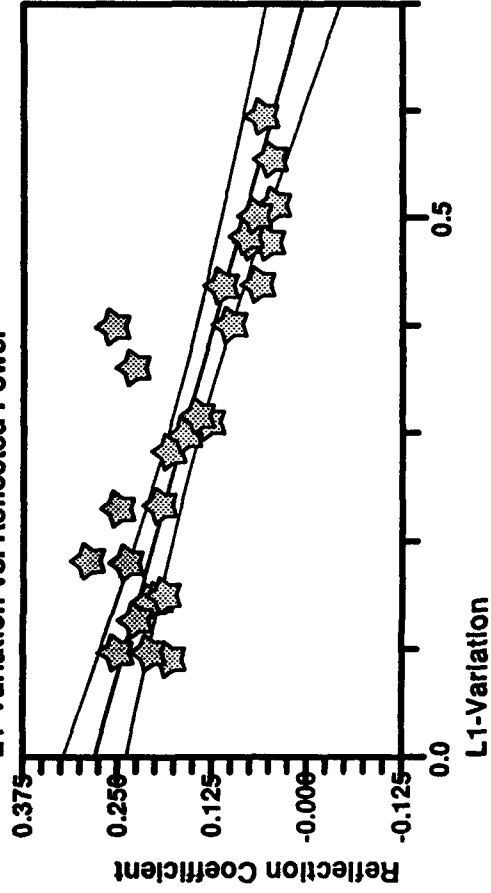
Standard LS: $S=0.057(0.013)$, $I=0.013(0.004)$, $\rho=0.67$

L1-Variation vs. Transmitted Power



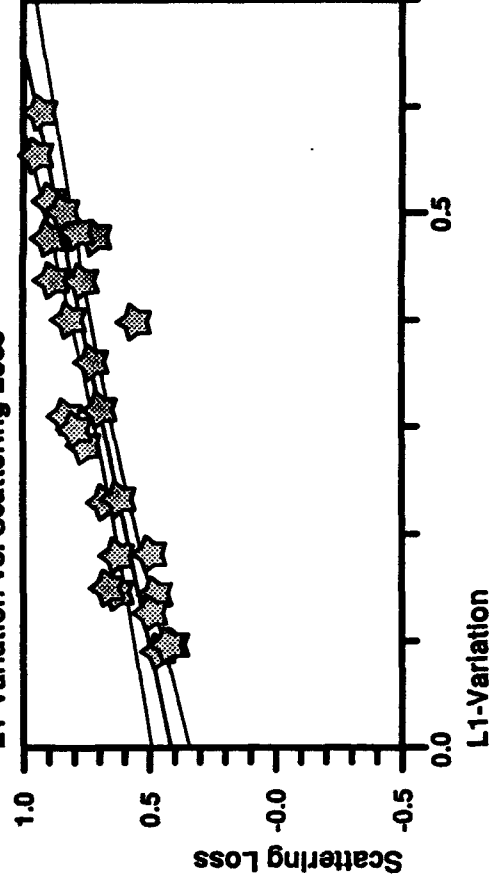
Standard LS: $S=-0.501(0.095)$, $I=0.306(0.033)$, $\rho=-0.73$

L1-Variation vs. Reflected Power



Standard LS: $S=-0.393(0.056)$, $I=0.280(0.020)$, $\rho=-0.81$

L1-Variation vs. Scattering Loss



Standard LS: $S=0.894(0.104)$, $I=0.413(0.036)$, $\rho=0.87$

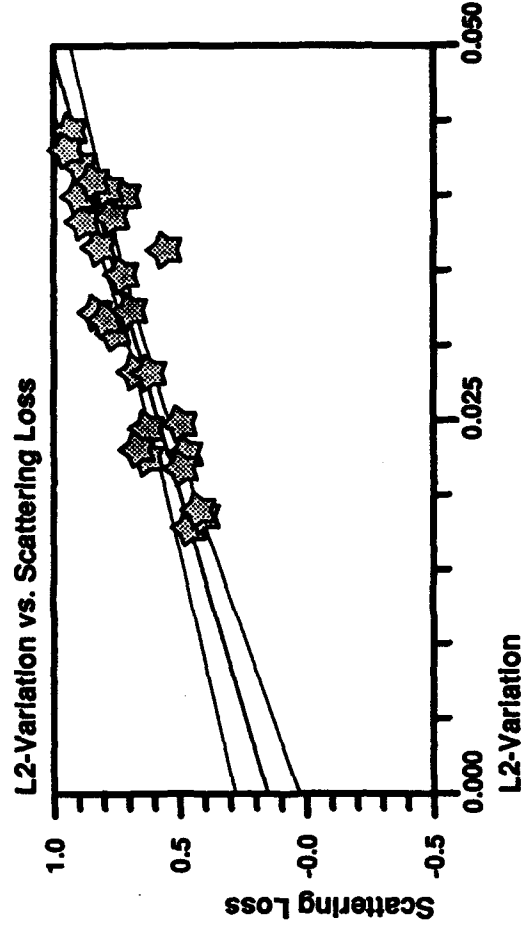
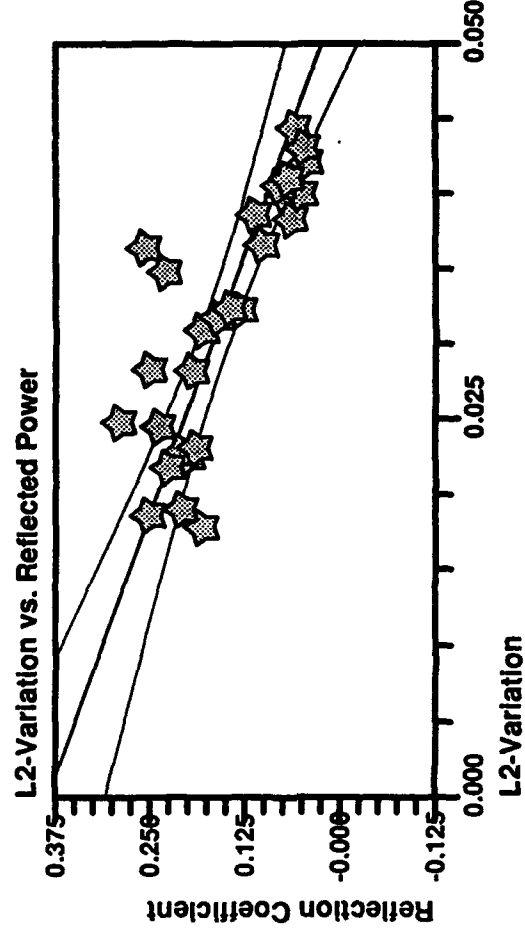
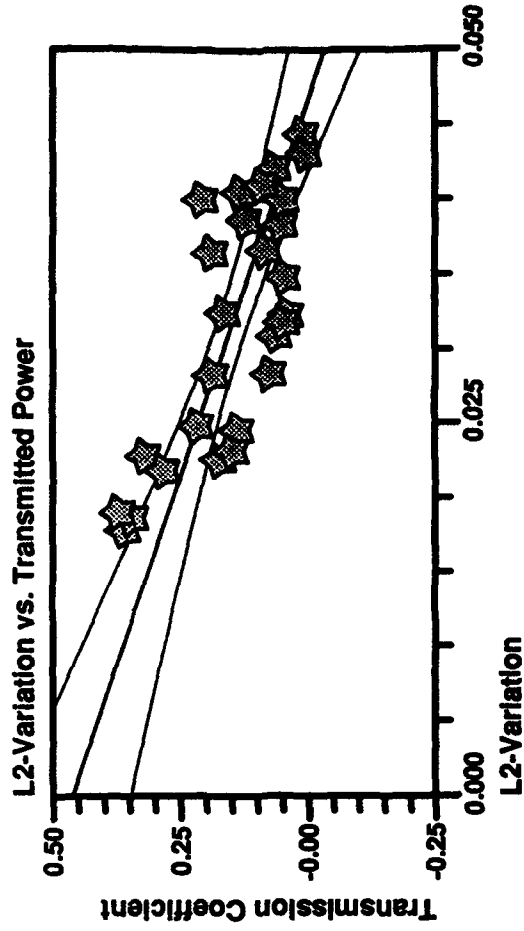
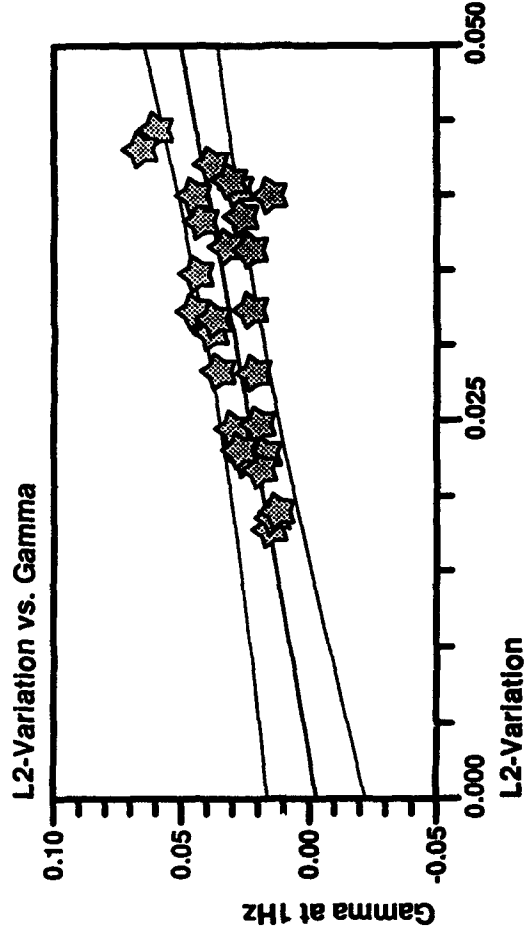


Figure 96

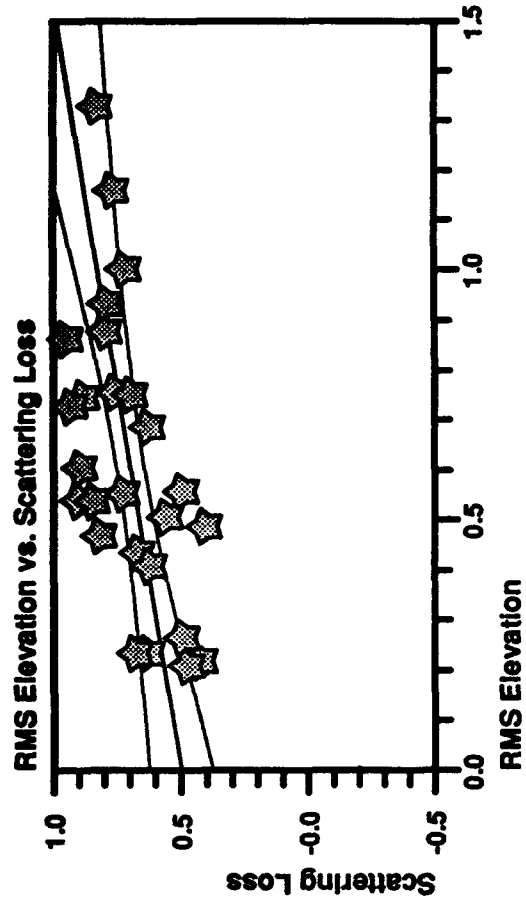
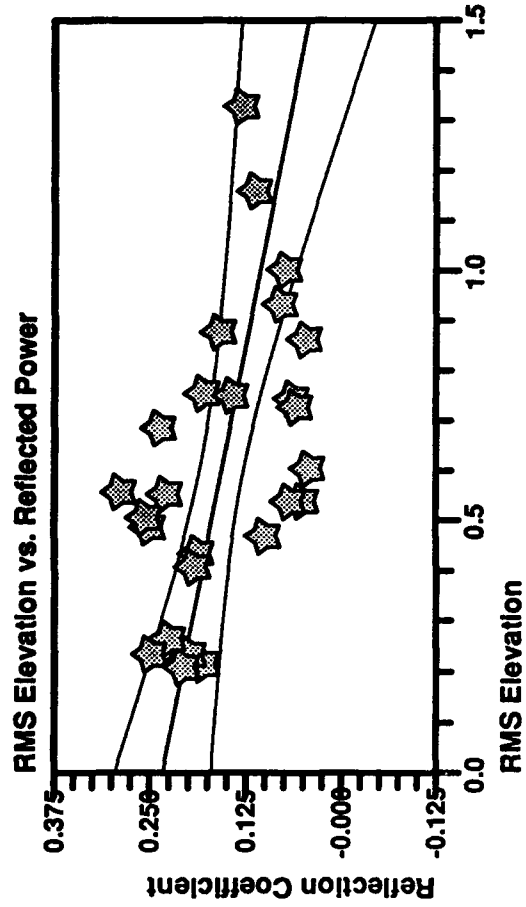
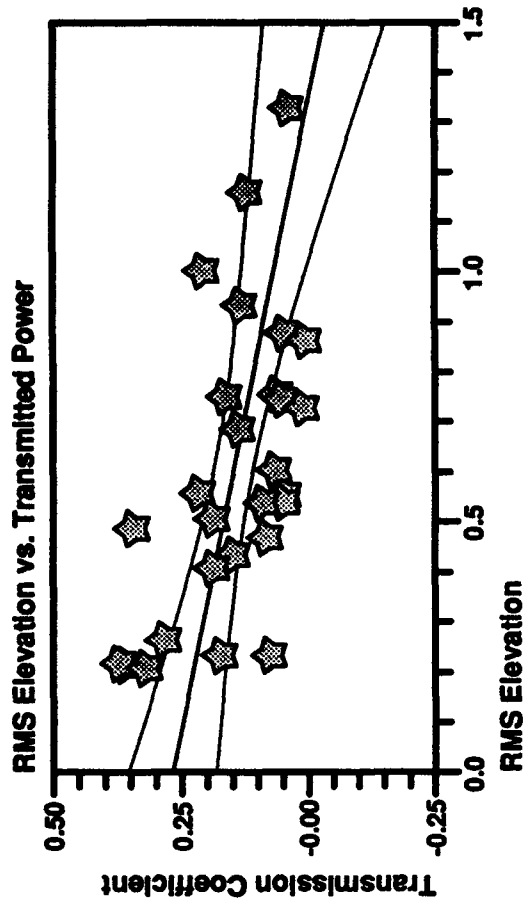
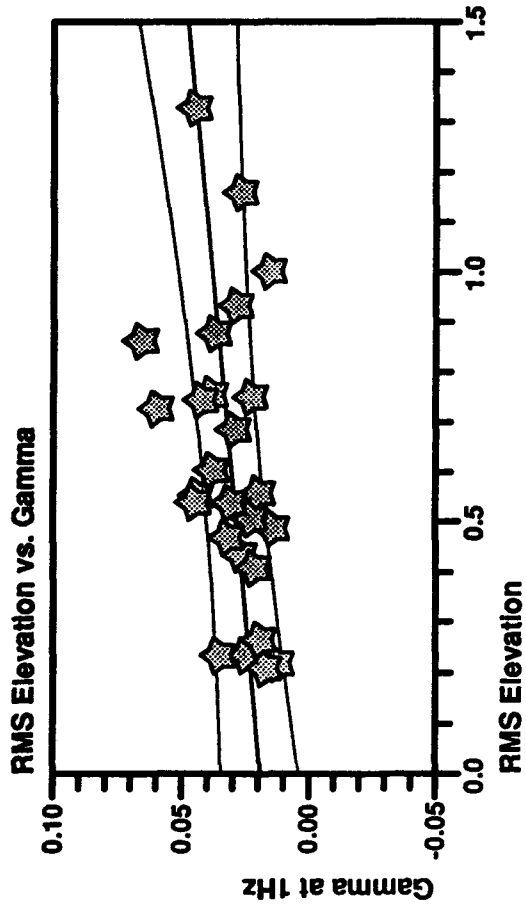


Figure 97

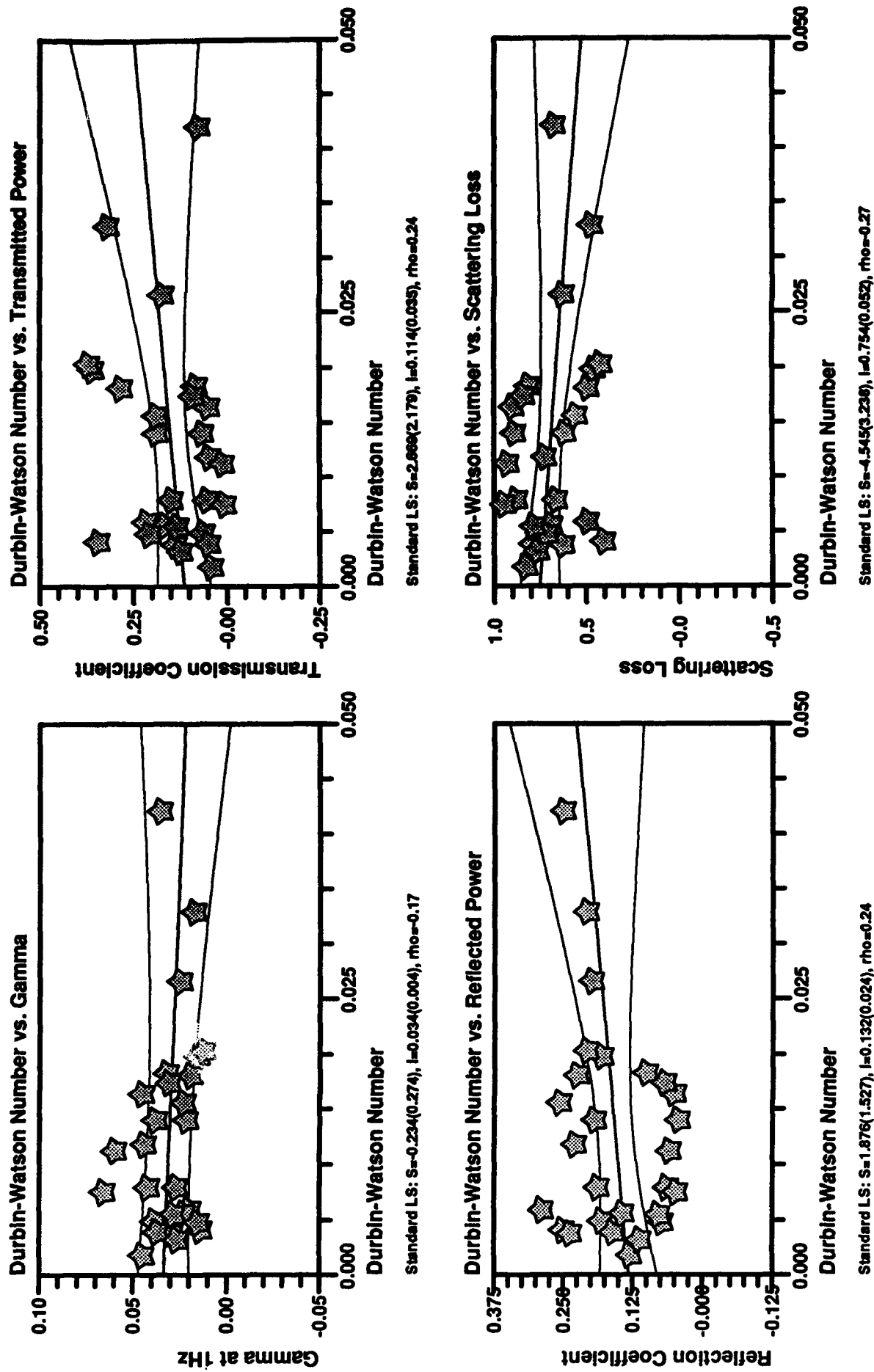


Figure 98

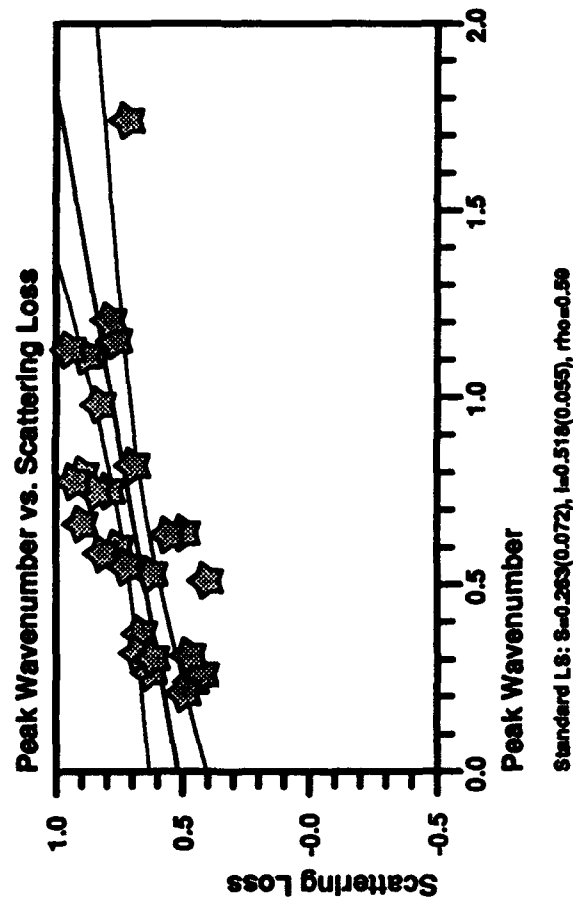
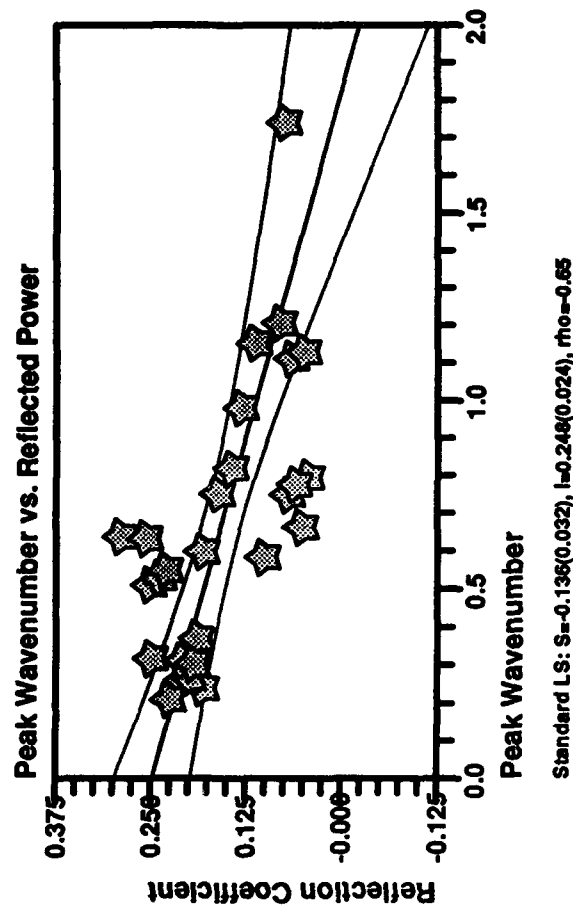
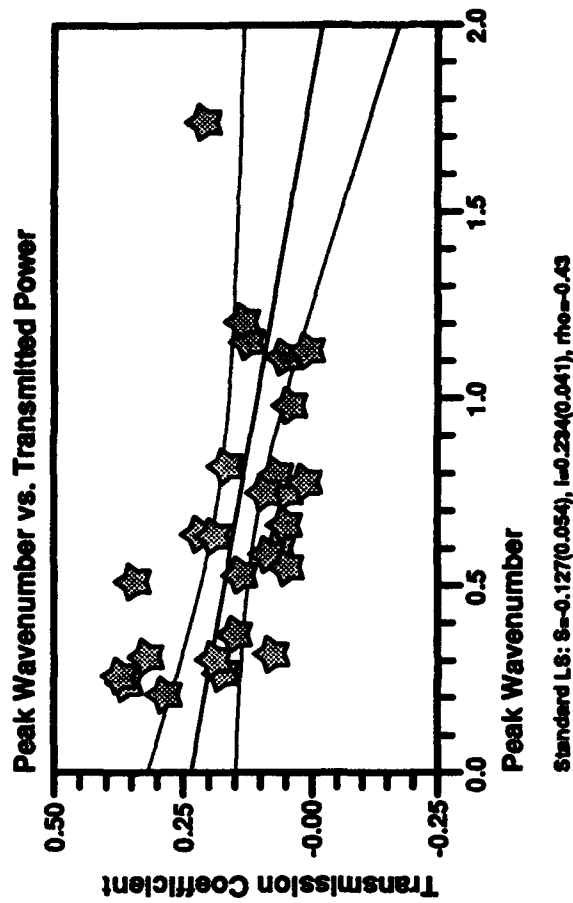
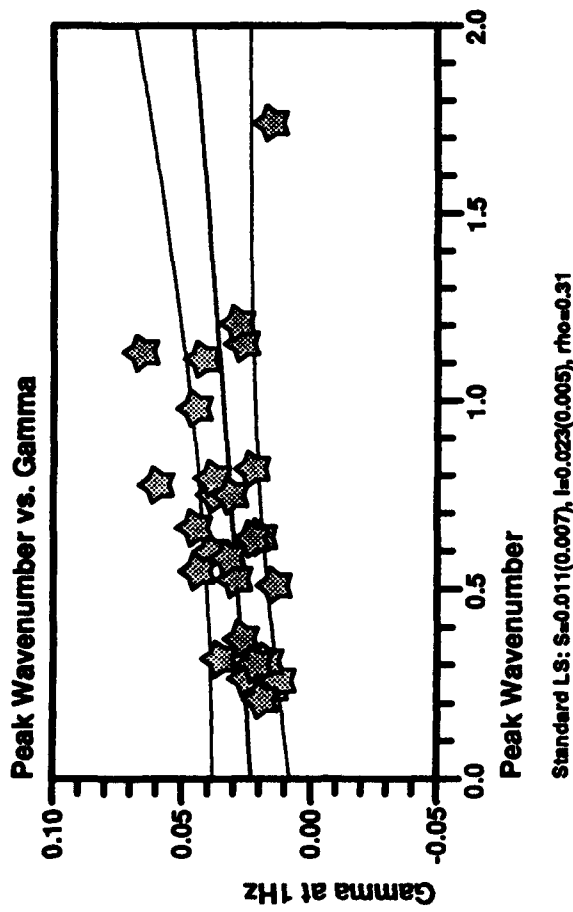


Figure 99

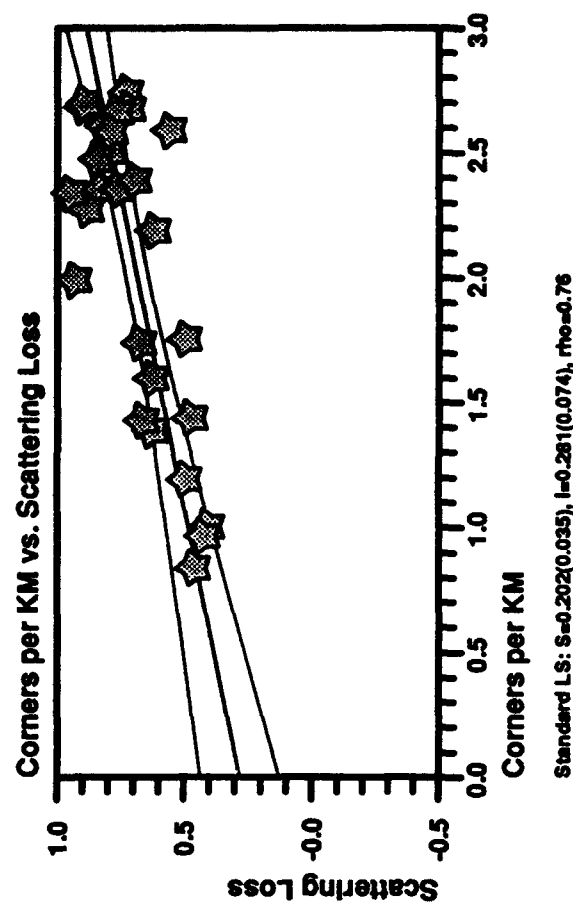
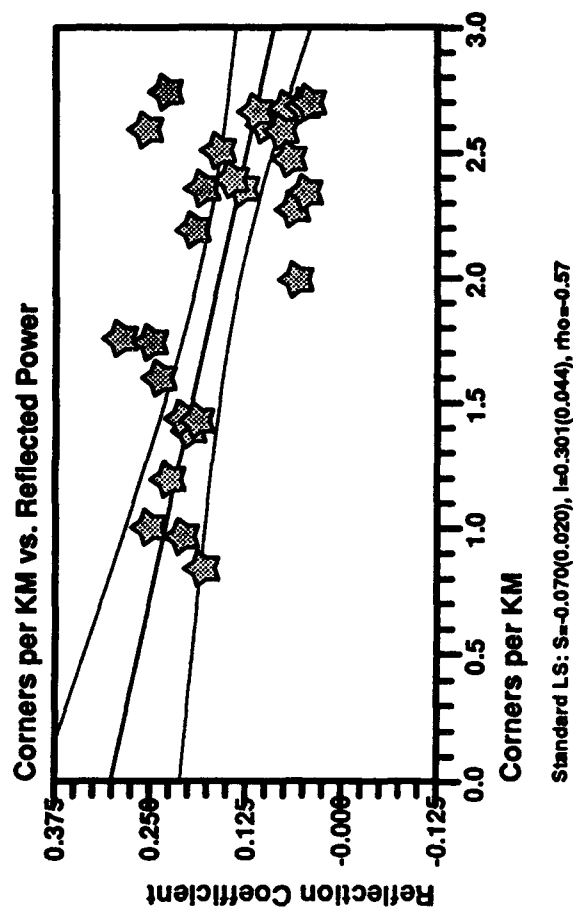
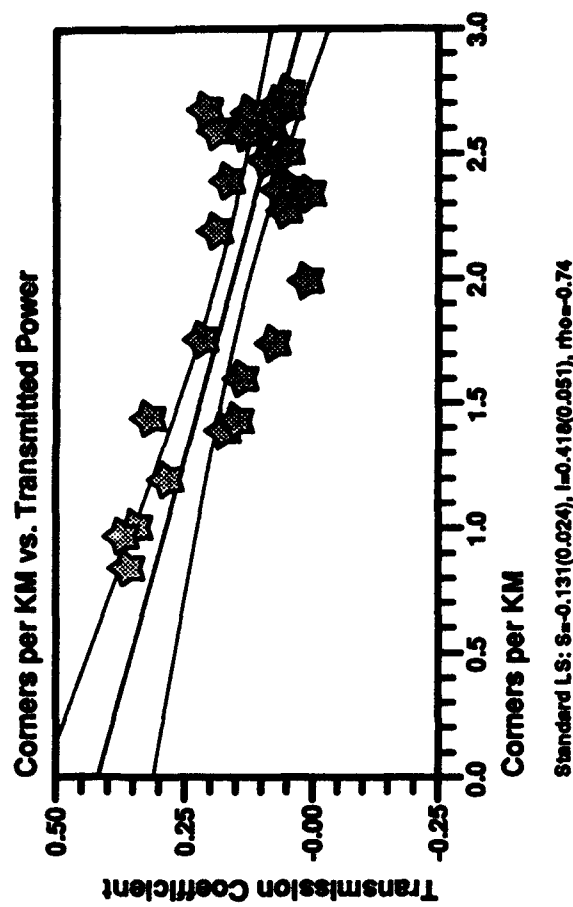
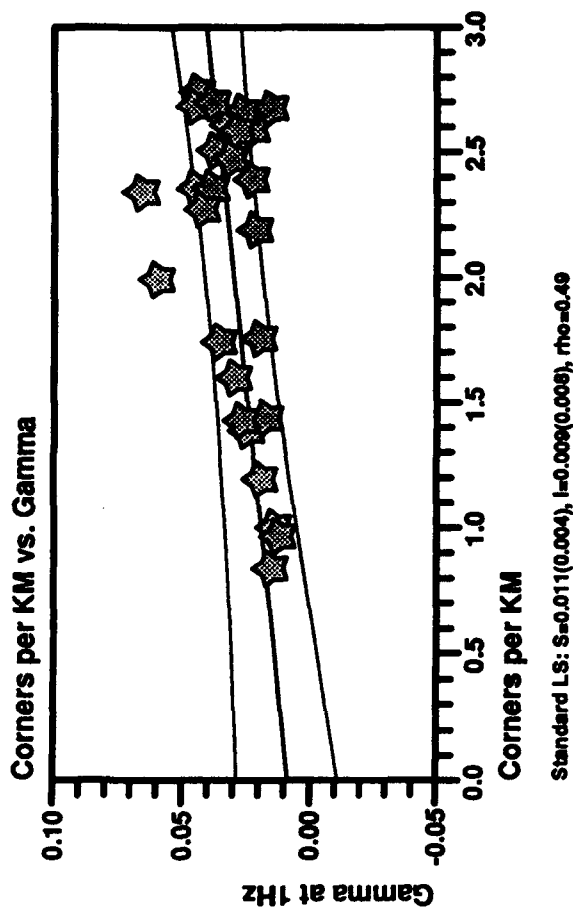


Figure 100

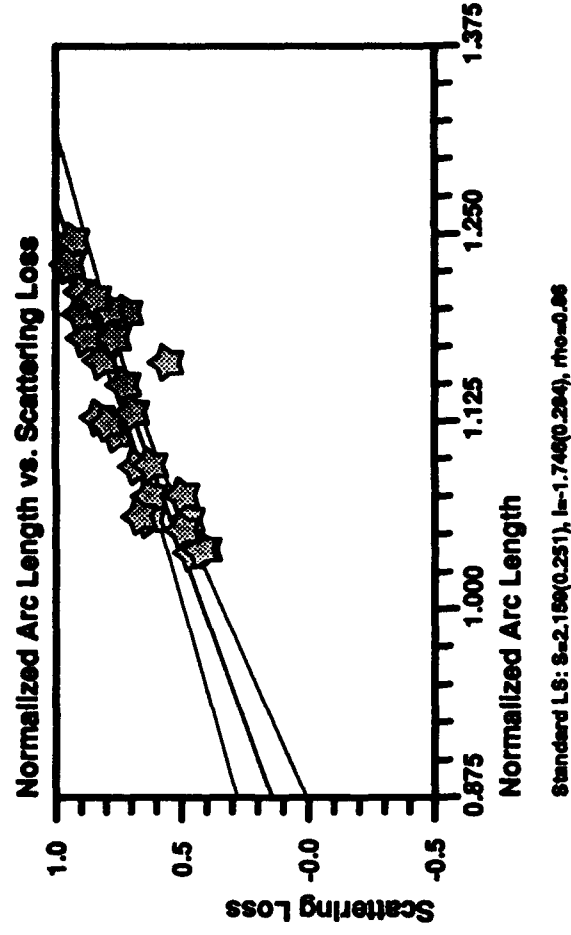
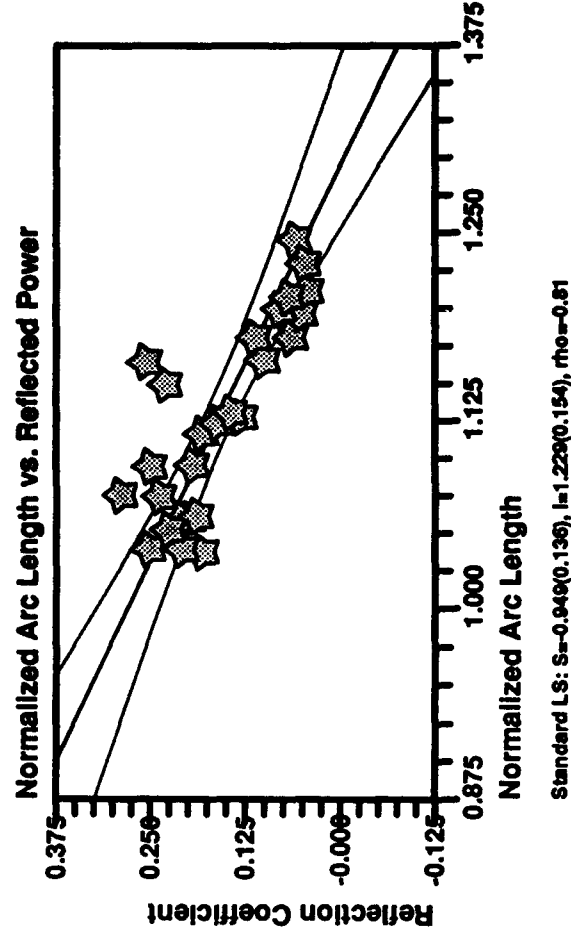
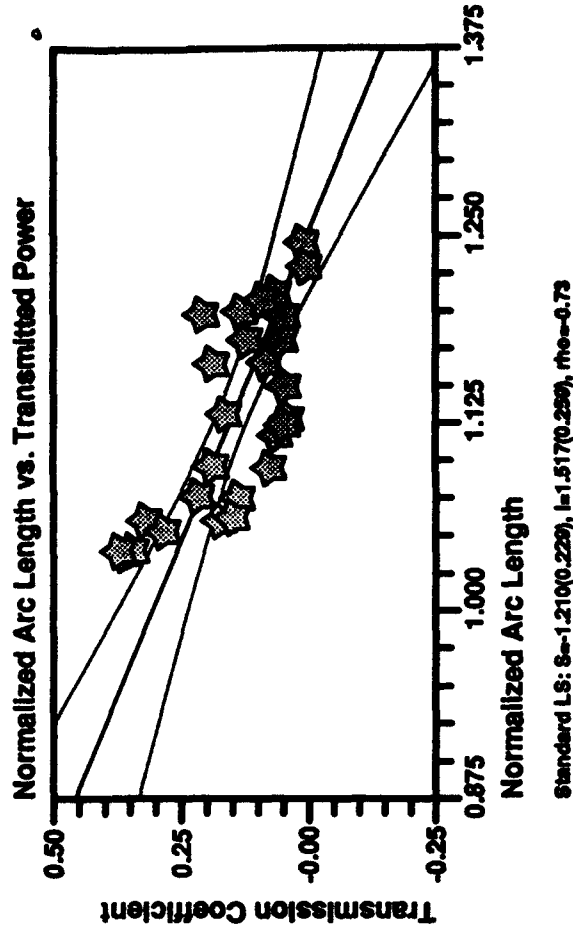
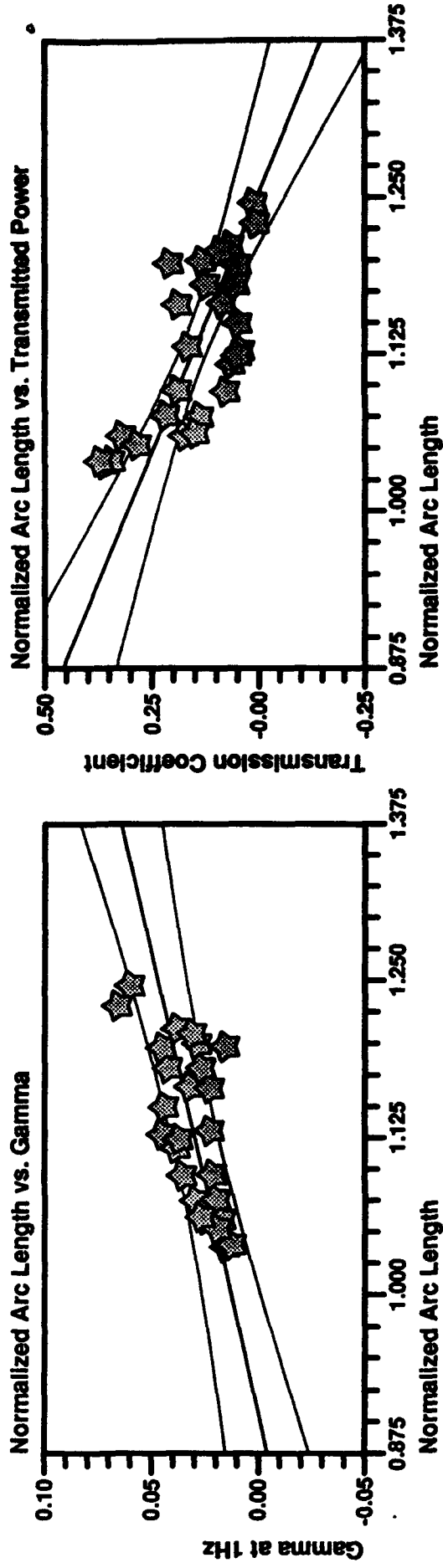


Figure 101

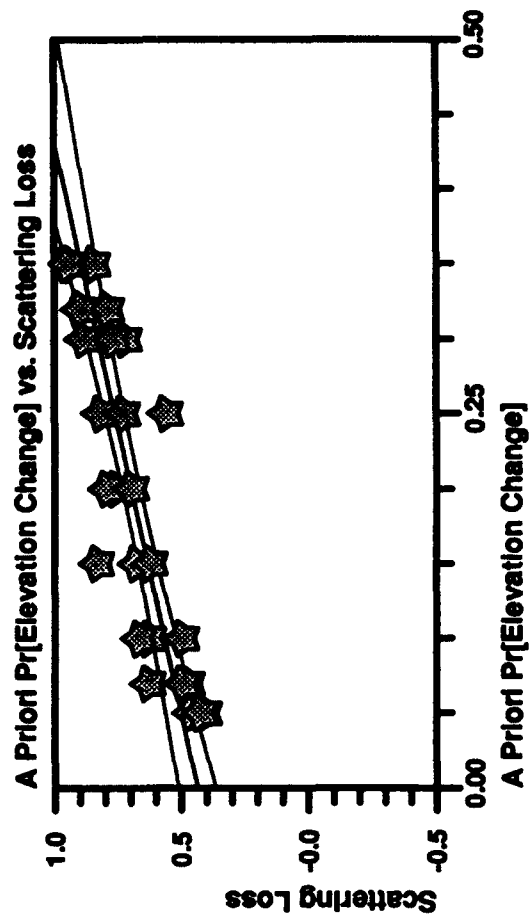
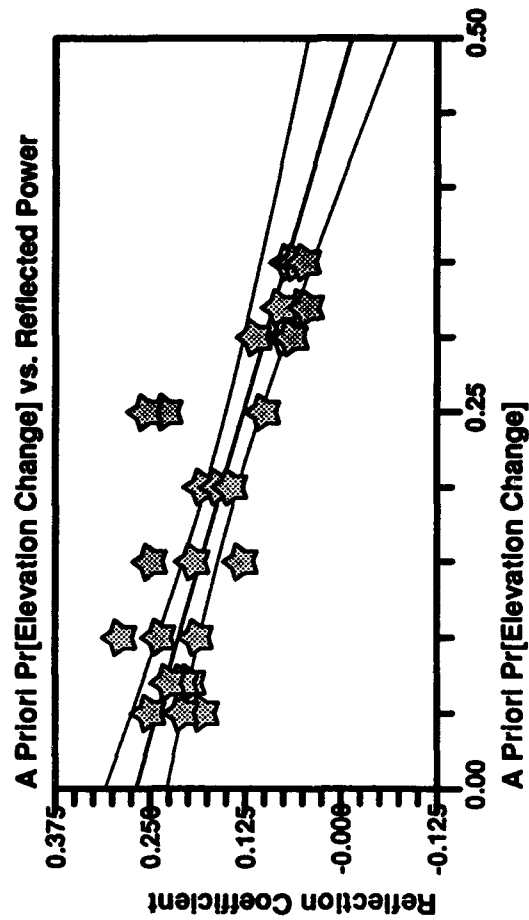
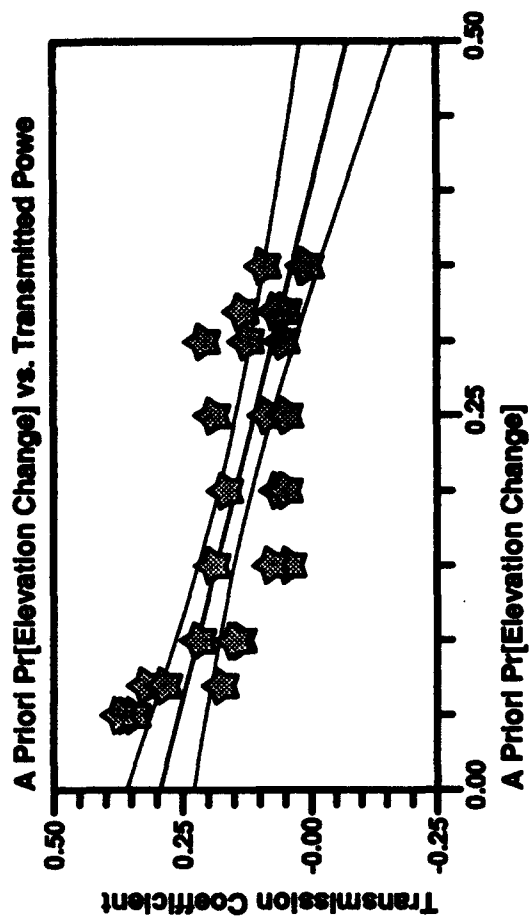
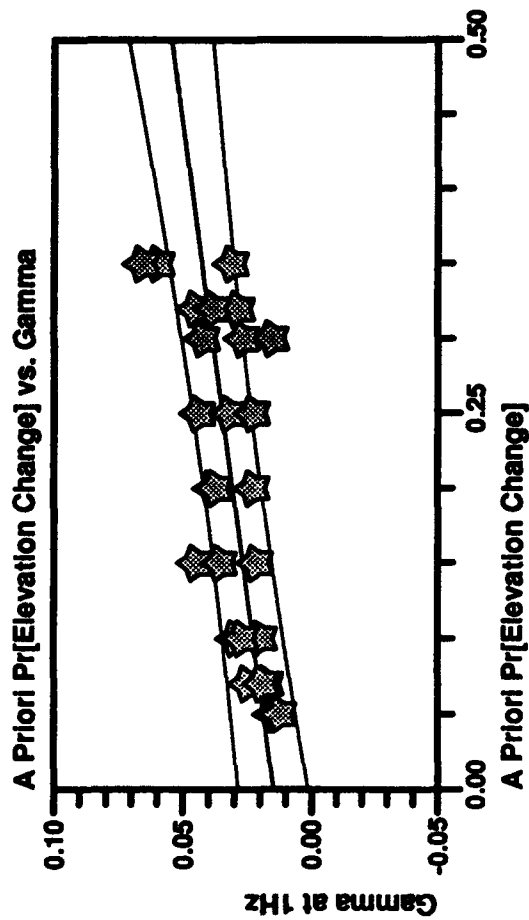
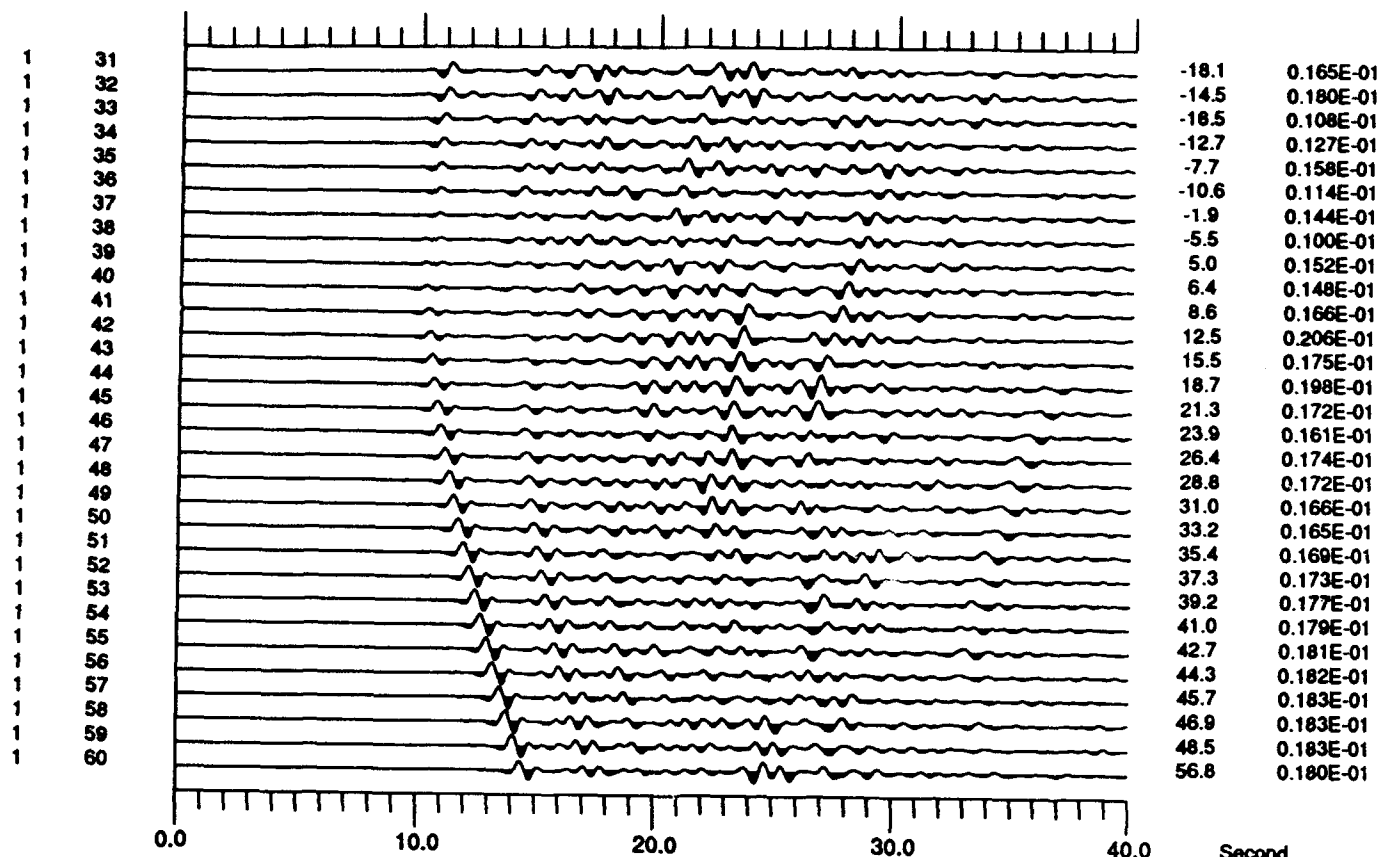
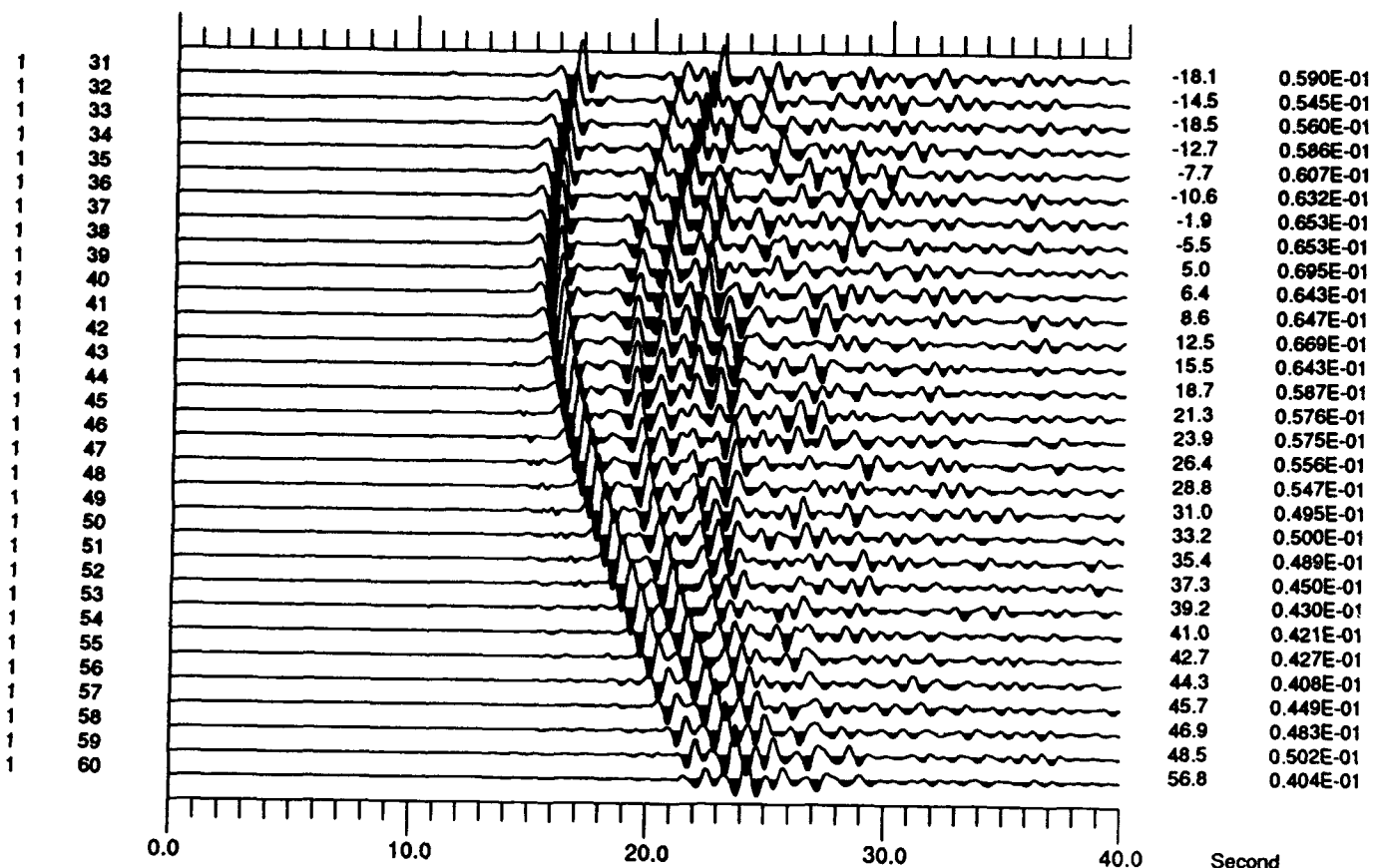


Figure 102



P, Model 11(seed 22887, Pr(1)=0.05)

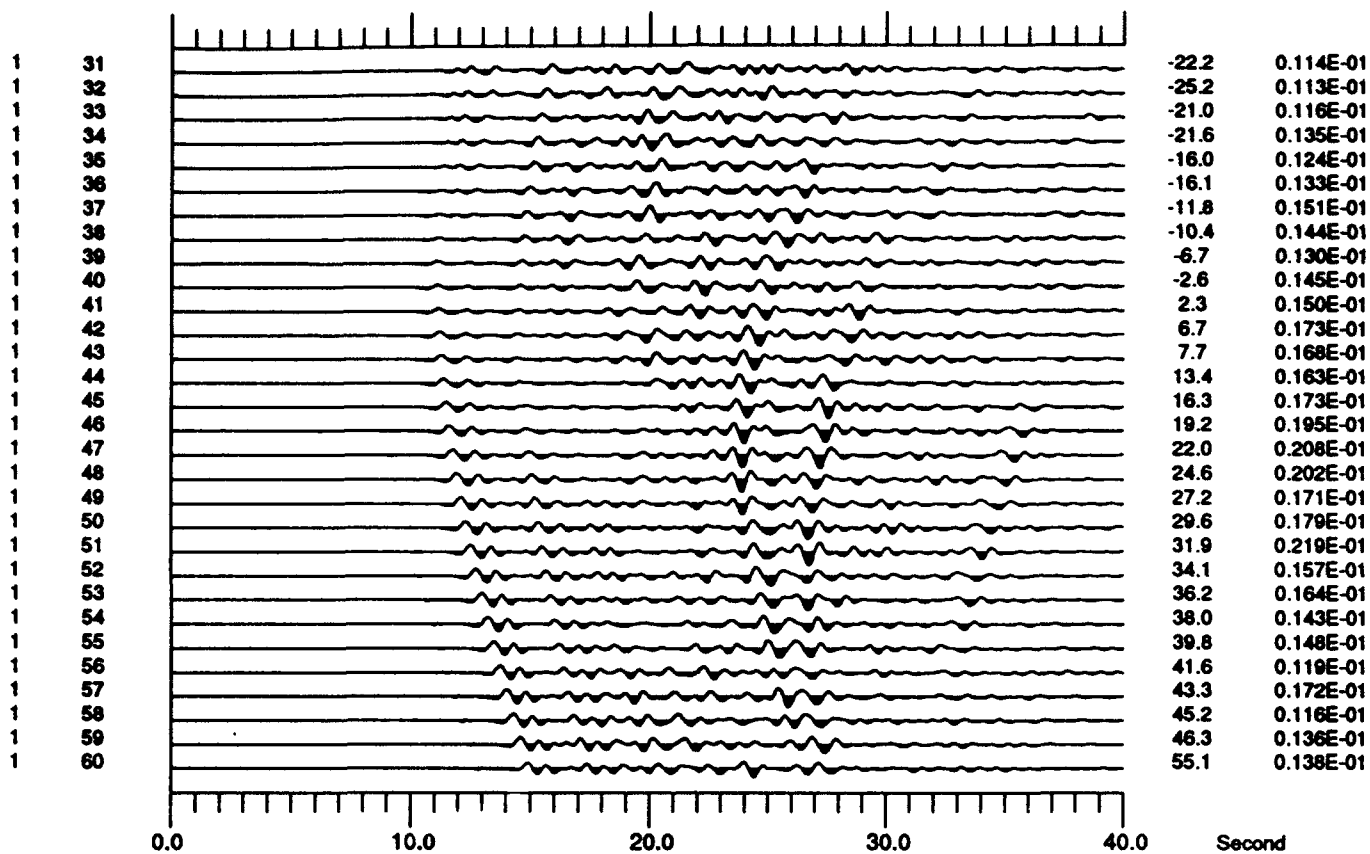
vert, same scale, decimated by 5



S, Model 11(seed 22887, Pr(1)=0.05)

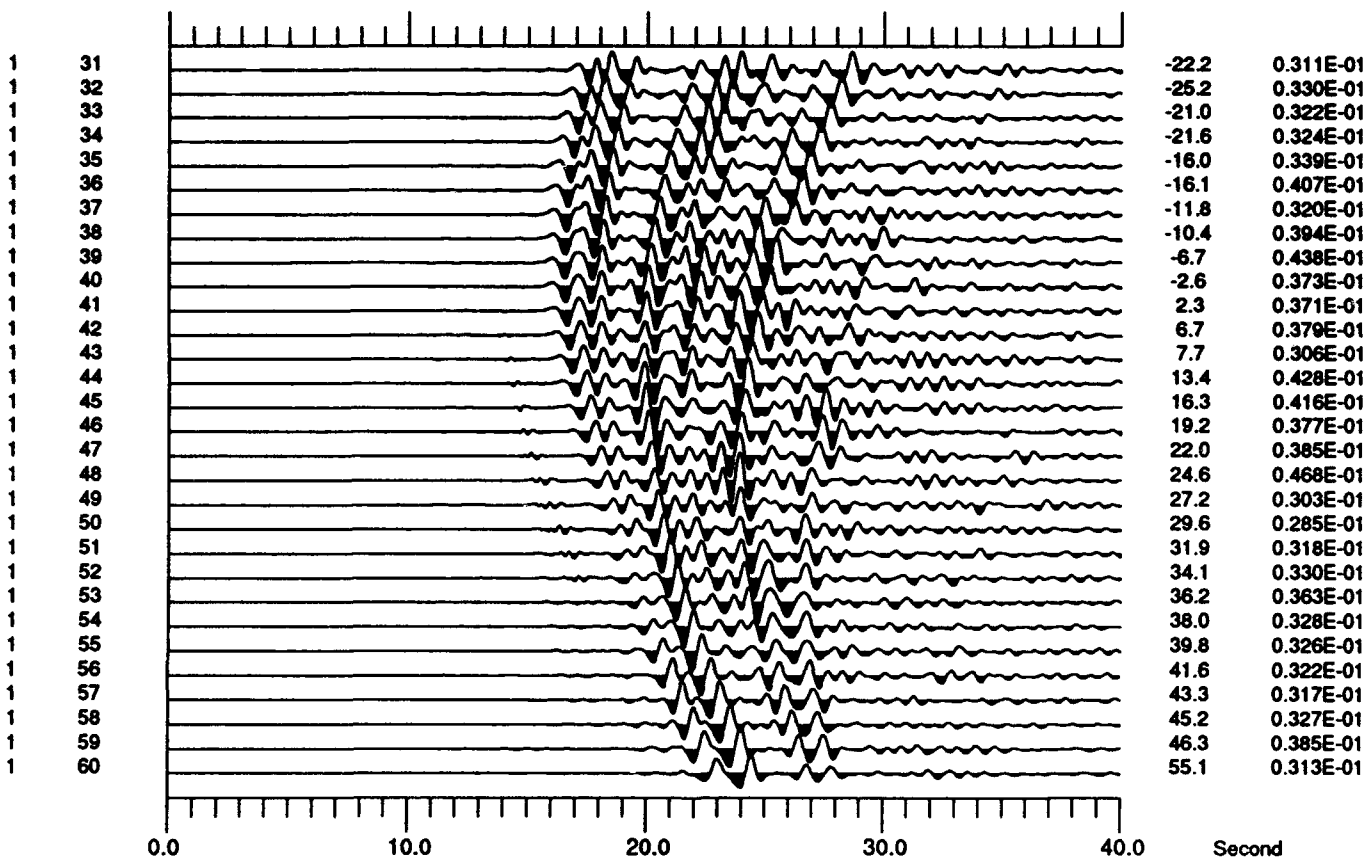
hori, same scale, decimated by 5

Figure 103



P, Model 12(seed 22892, Pr(1)=0.05)

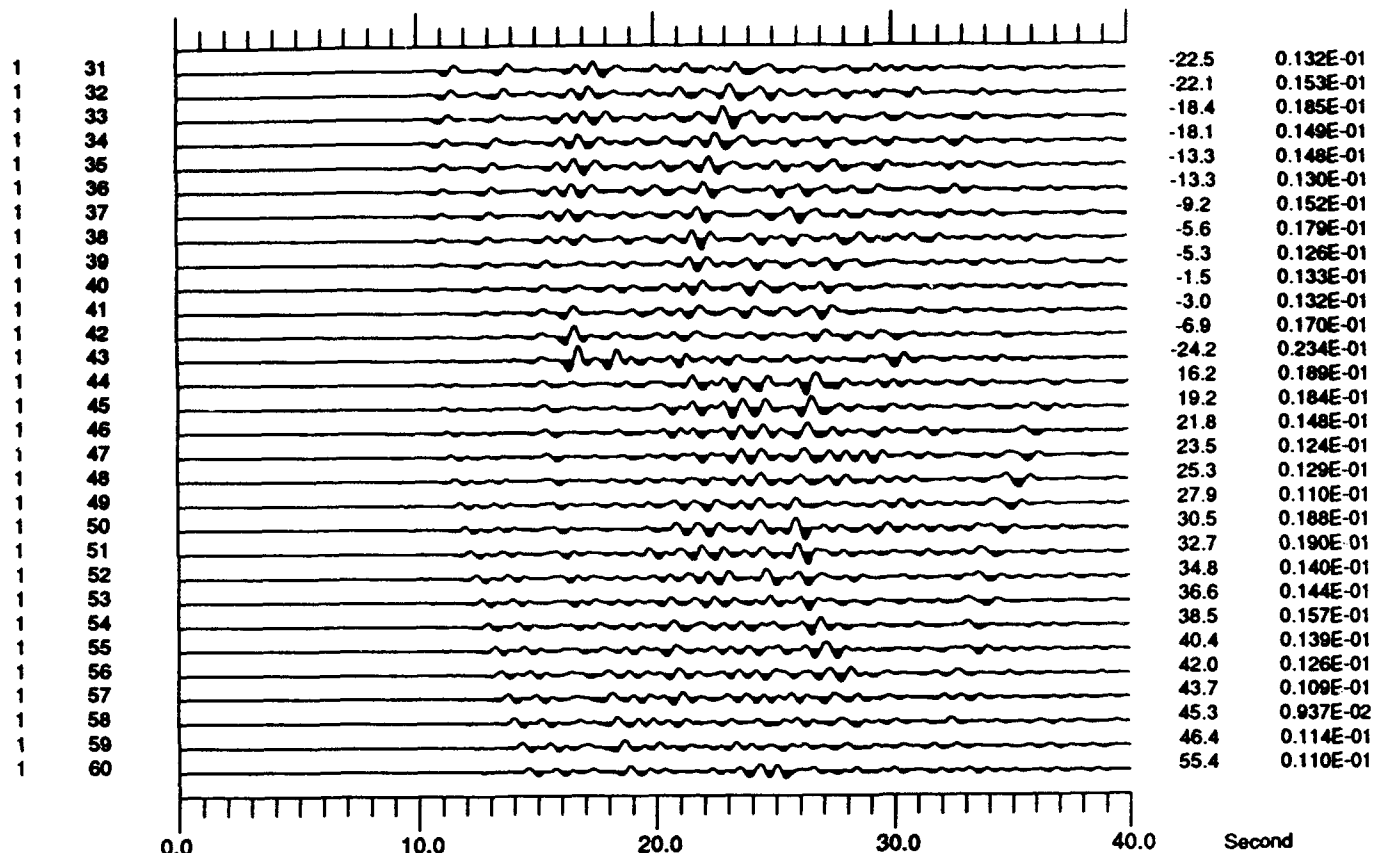
vert, same scale, decimated by 5



S, Model 12(seed 22892, Pr(1)=0.05)

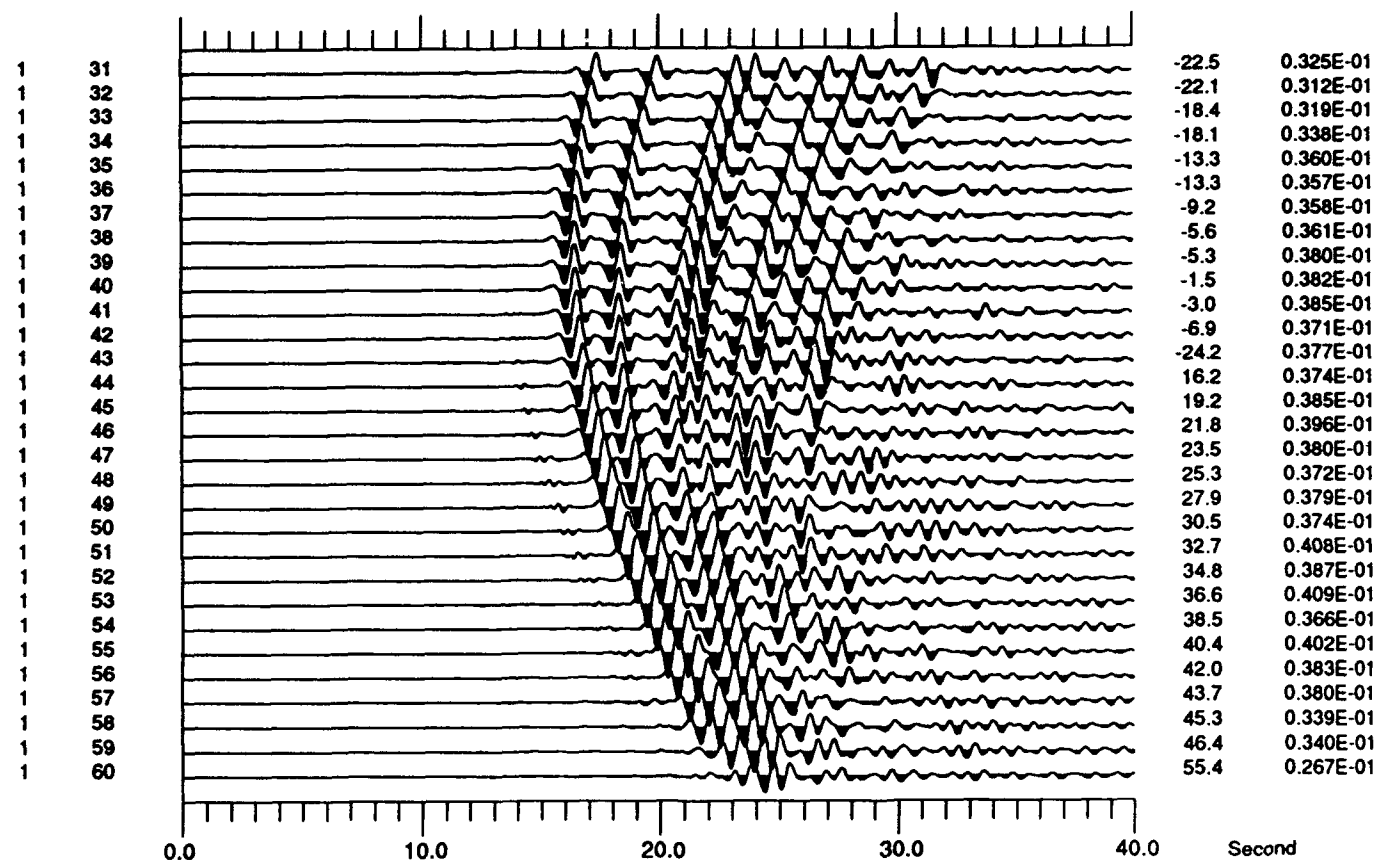
hori, same scale, decimated by 5

Figure 104



P, Model 13(seed 85995, Pr(1)=0.05)

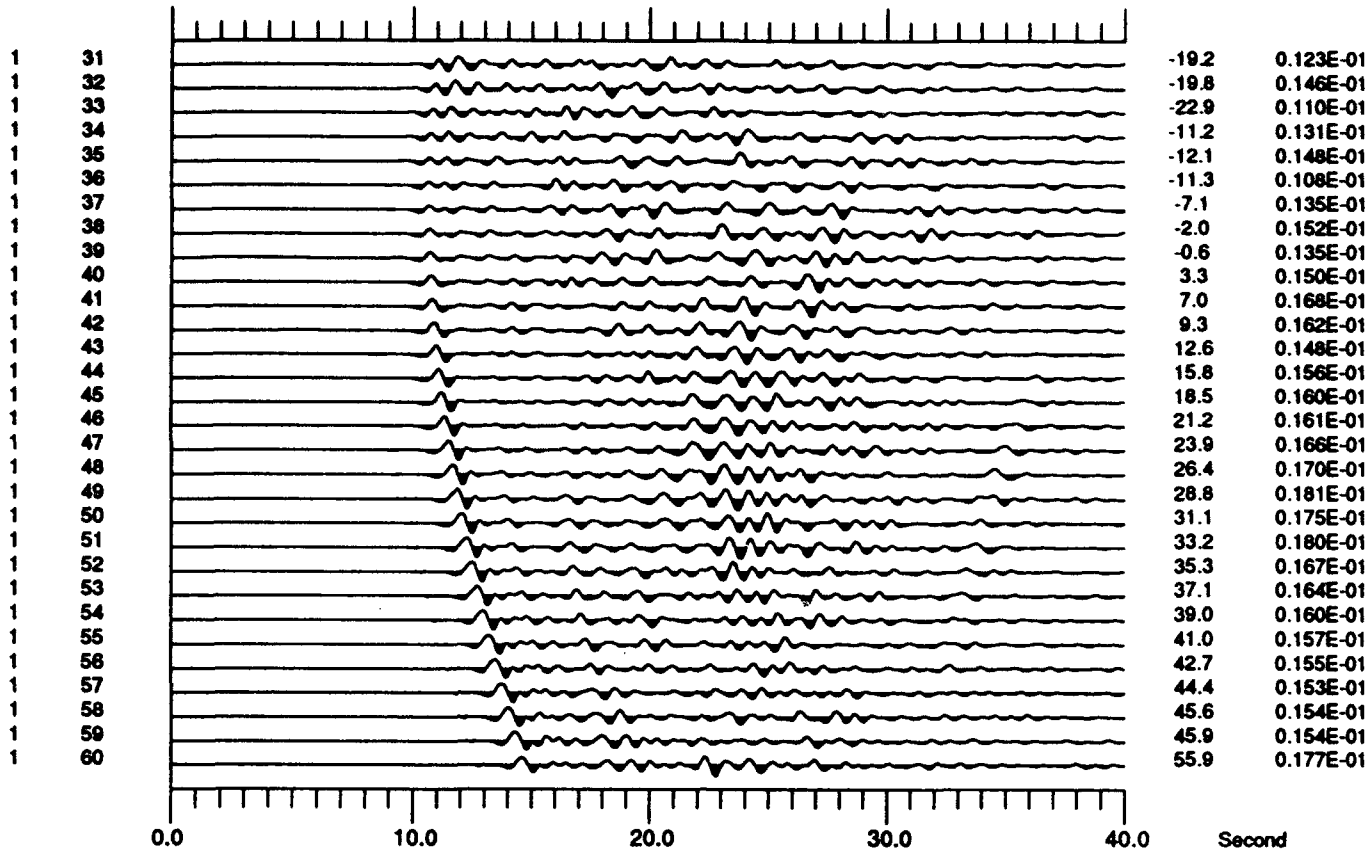
vert, same scale, decimated by 5



S, Model 13(seed 85995, Pr(1)=0.05)

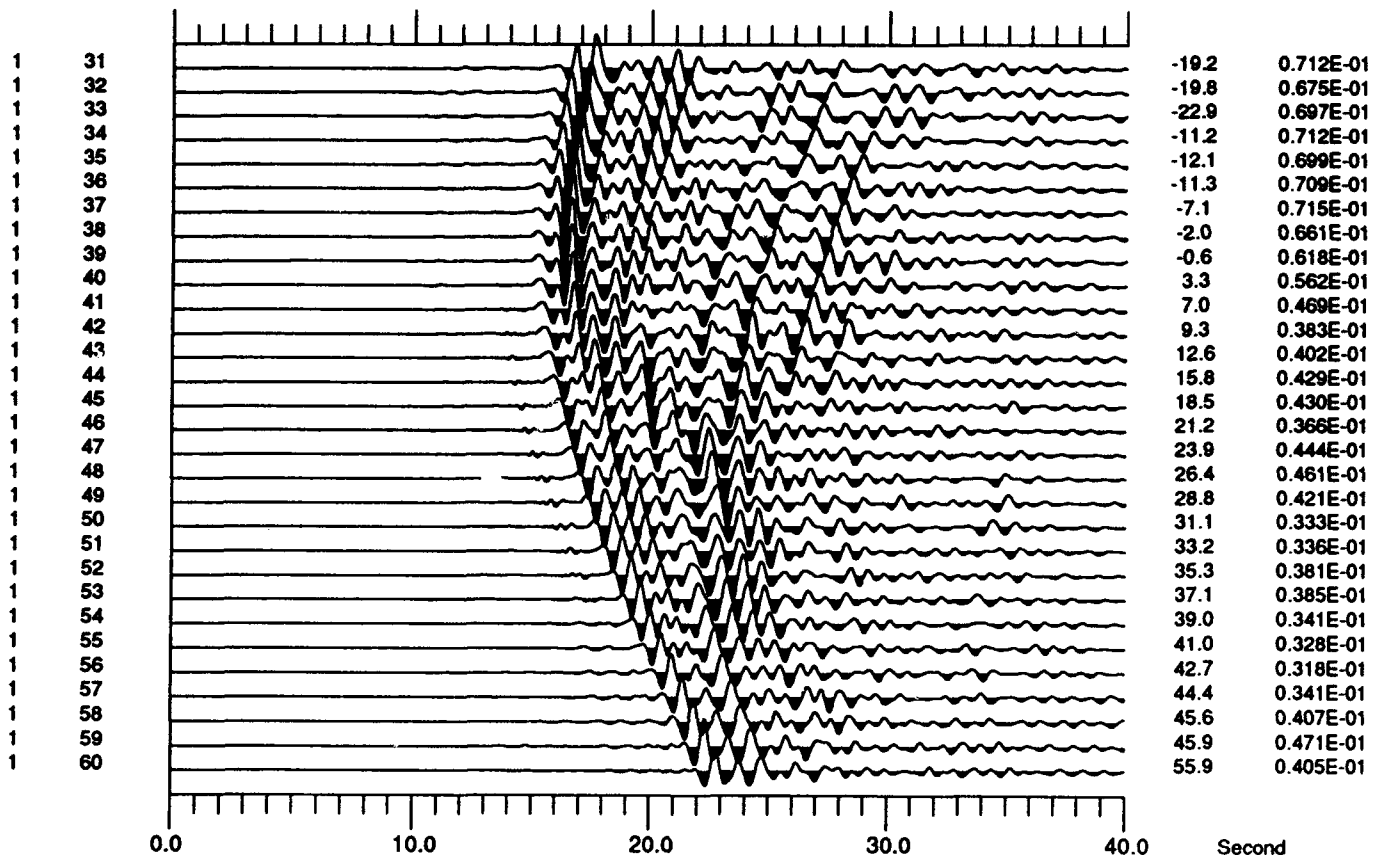
hori, same scale, decimated by 5

Figure 105



P, Model 14(seed 91333, Pr(1)=0.07)

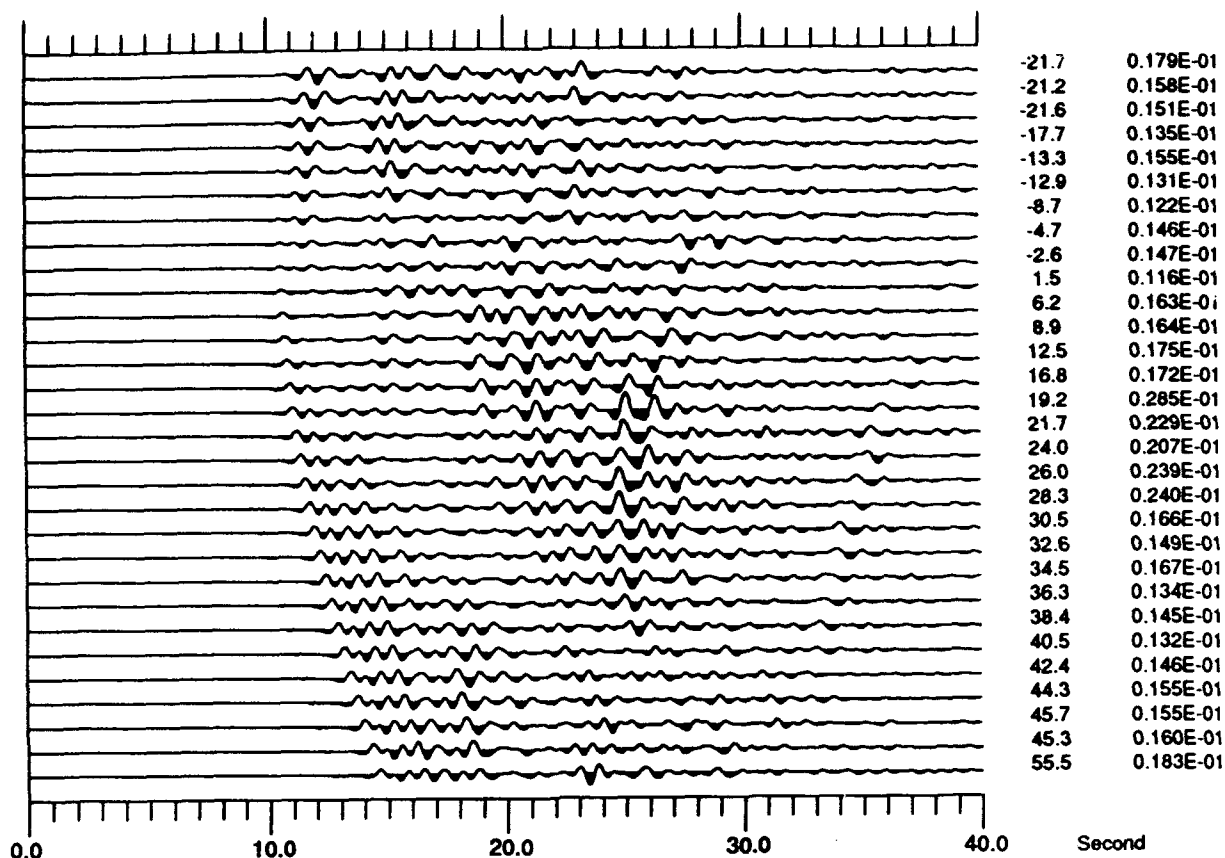
vert, same scale, decimated by 5



S, Model 14(seed 91333, Pr(1)=0.07)

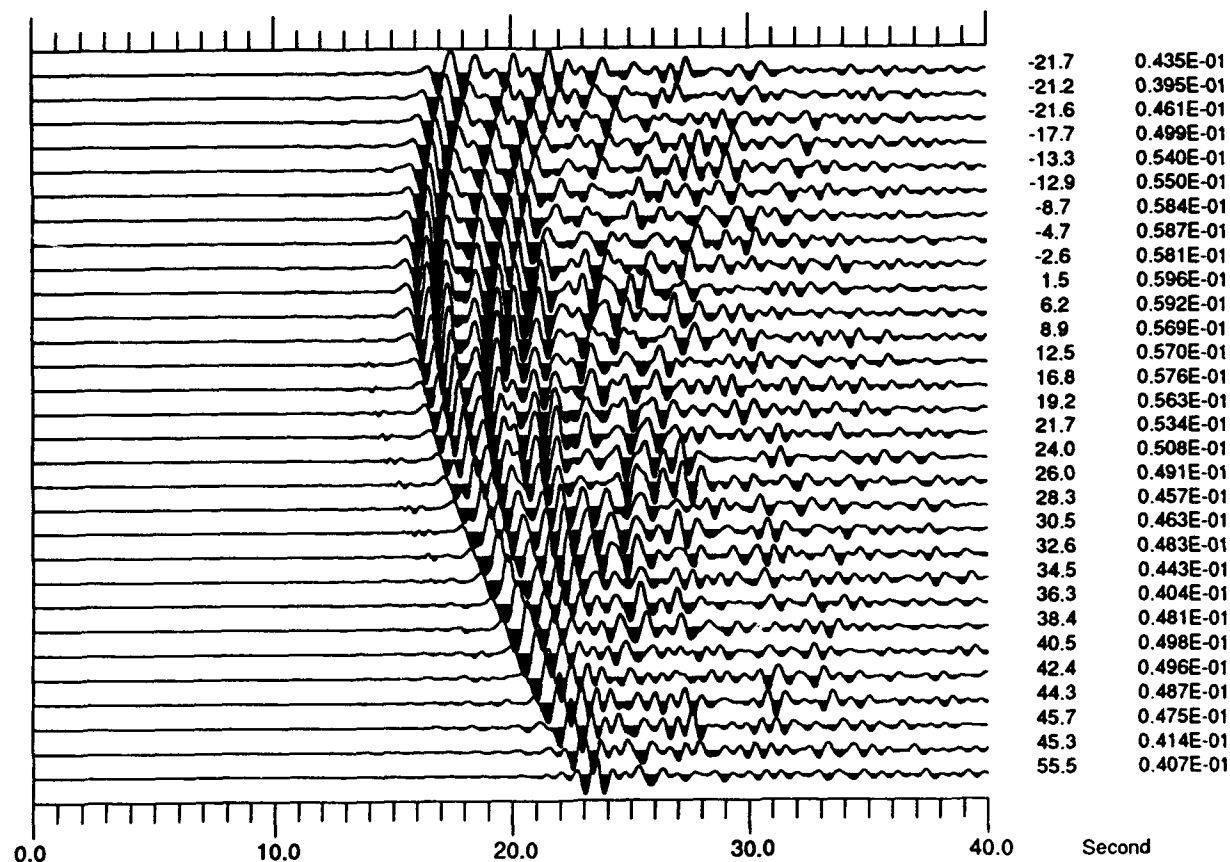
hori, same scale, decimated by 5

Figure 106



P, Model 15(seed 91350, Pr(1)=0.07)

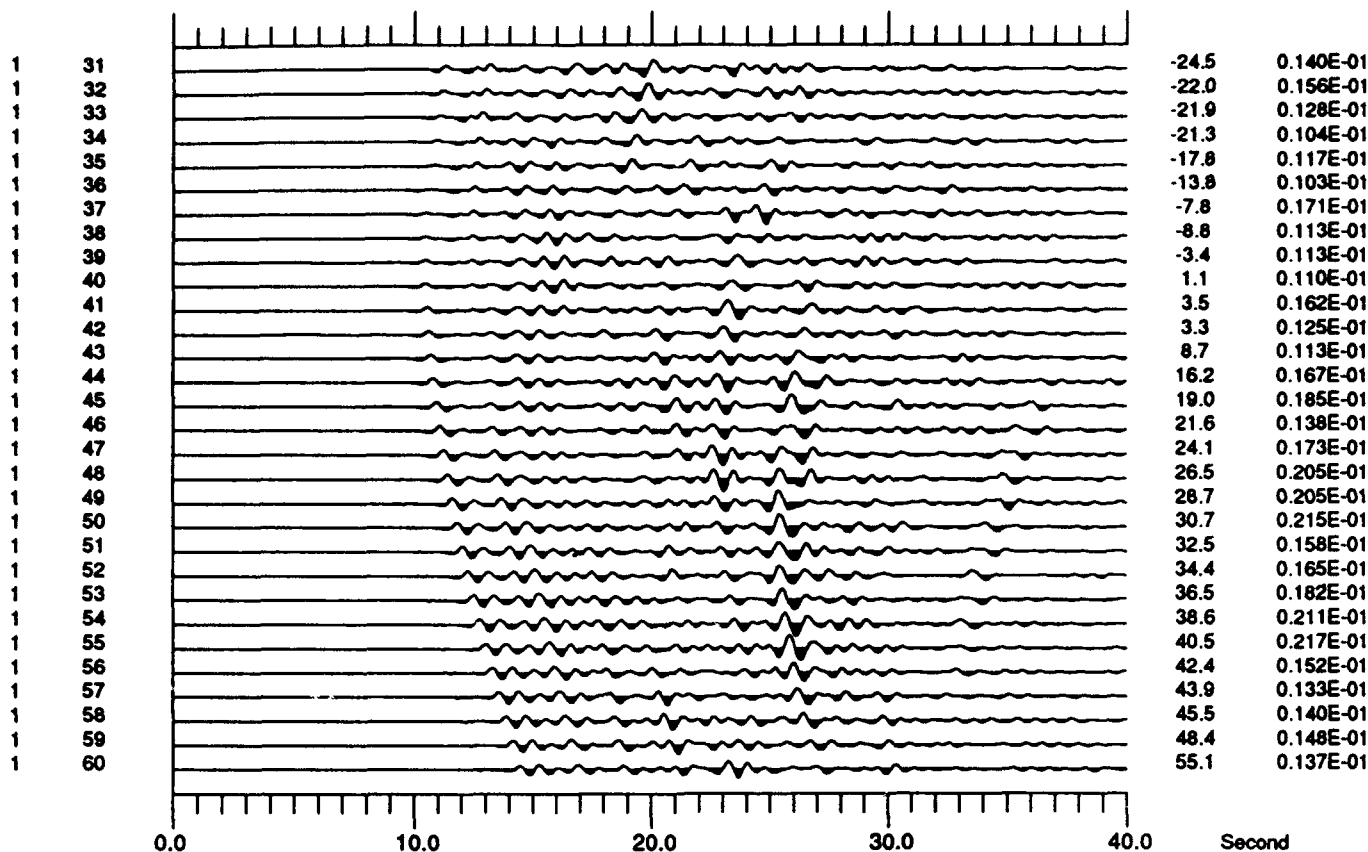
vert, same scale, decimated by 5



S, Model 15(seed 91350, Pr(1)=0.07)

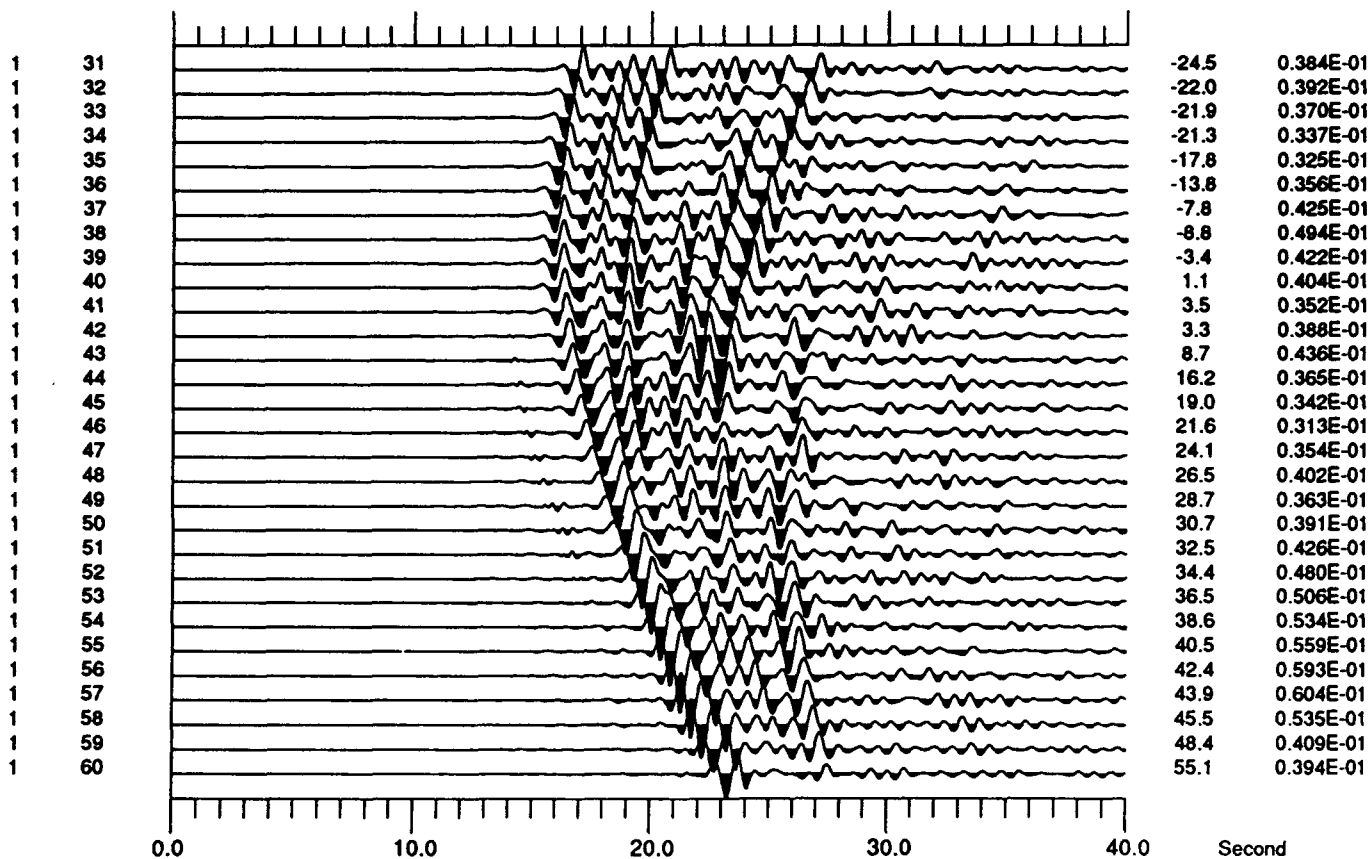
hori, same scale, decimated by 5

Figure 107



P, Model 16(seed 91285, Pr(1)=0.07)

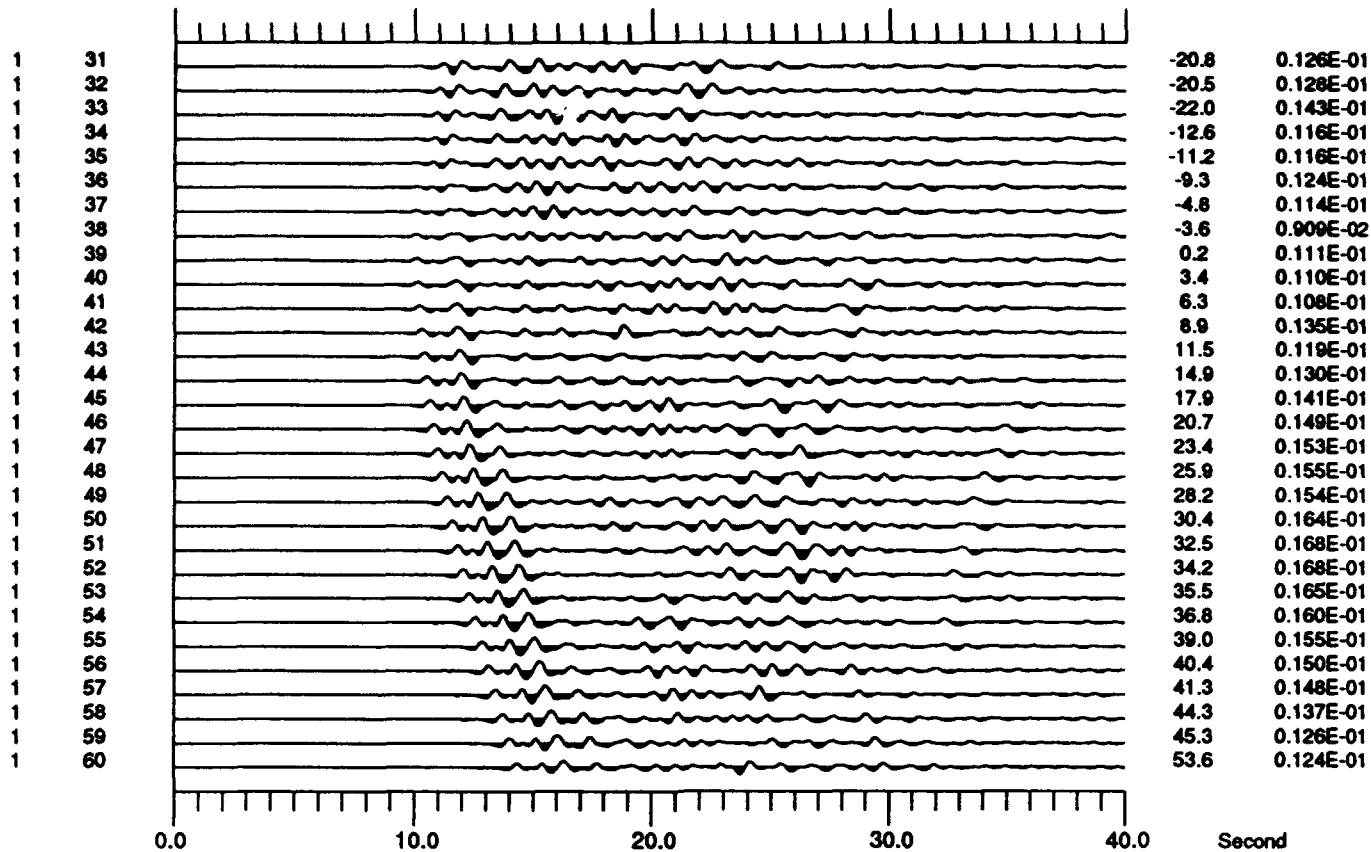
vert, same scale, decimated by 5



S, Model 16(seed 91285, Pr(1)=0.07)

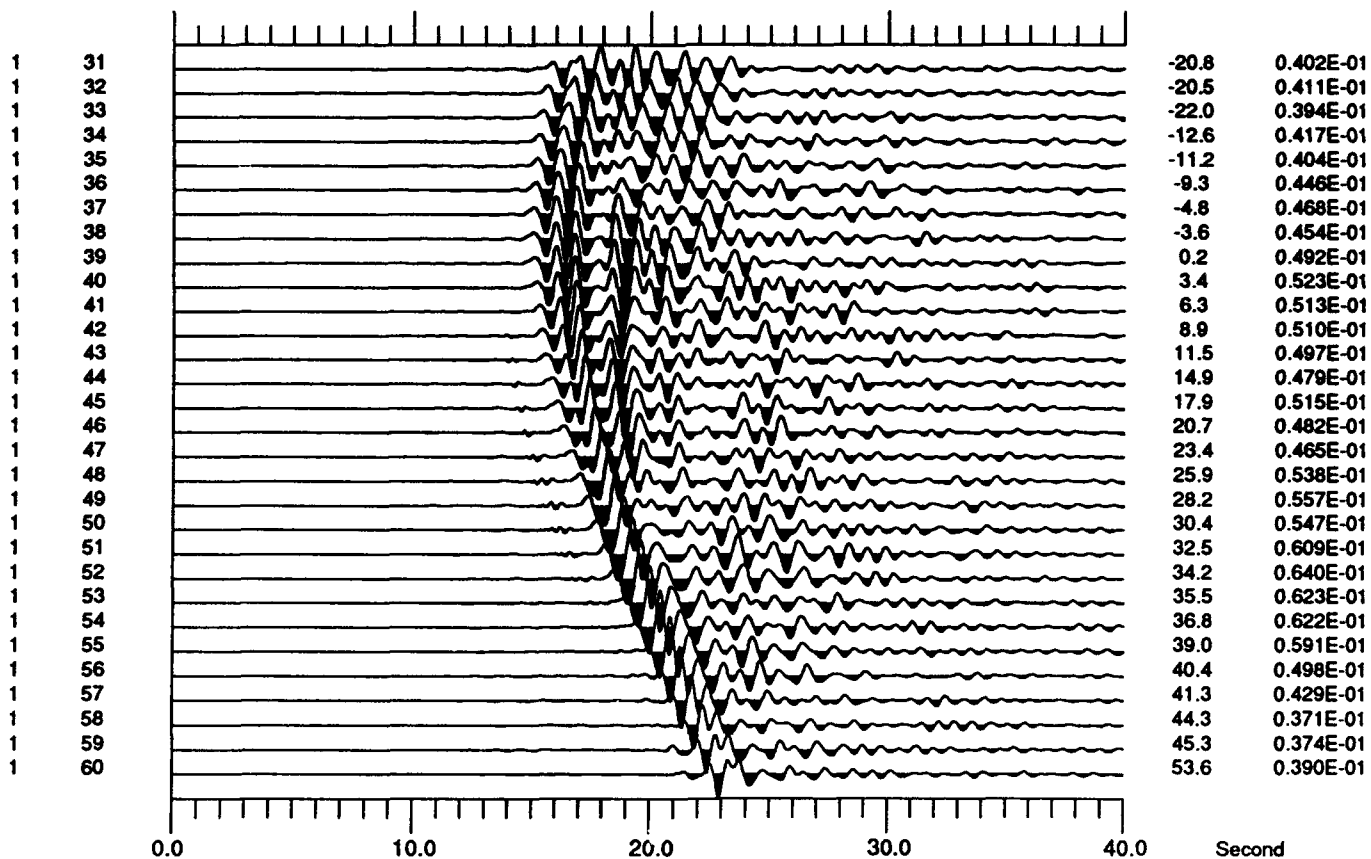
hori, same scale, decimated by 5

Figure 108



P, Model 21(seed 93337, Pr(1)=0.10)

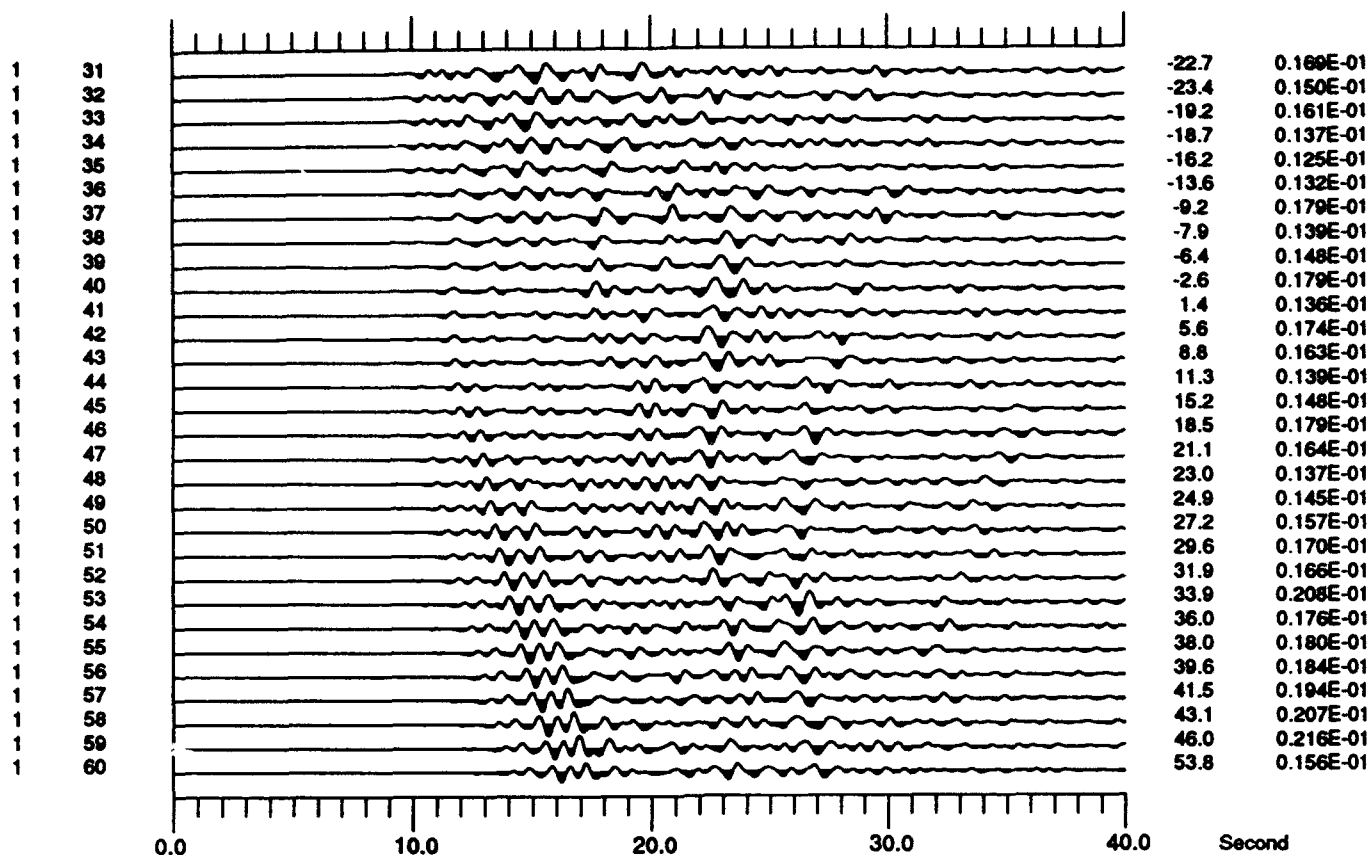
vert, same scale, decimated by 5



S, Model 21(seed 93337, Pr(1)=0.10)

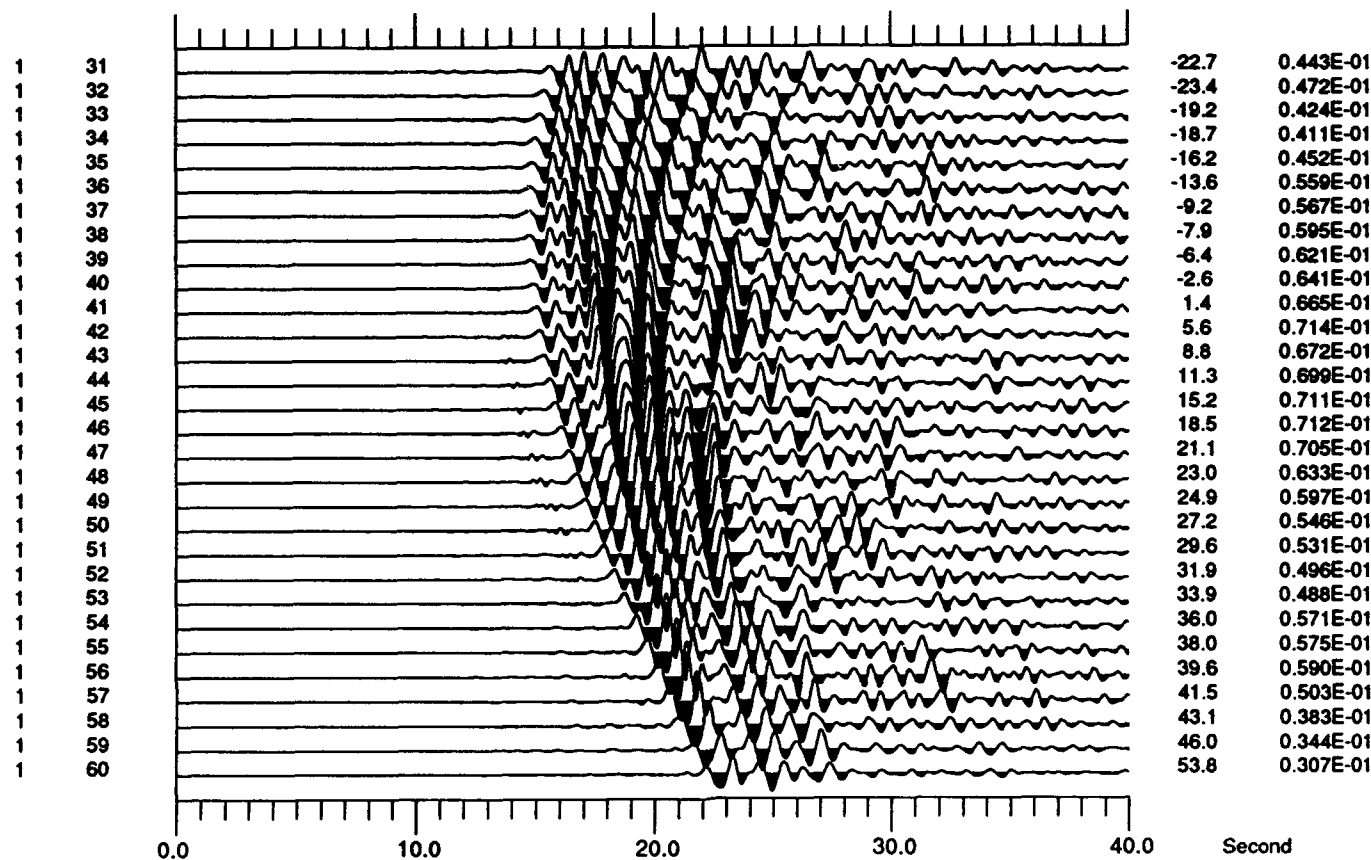
hori, same scale, decimated by 5

Figure 109



P, Model 22(seed 93347, Pr(1)=0.10)

vert, same scale, decimated by 5



S, Model 22(seed 93347, Pr(1)=0.10)

hori, same scale, decimated by 5

Figure 110

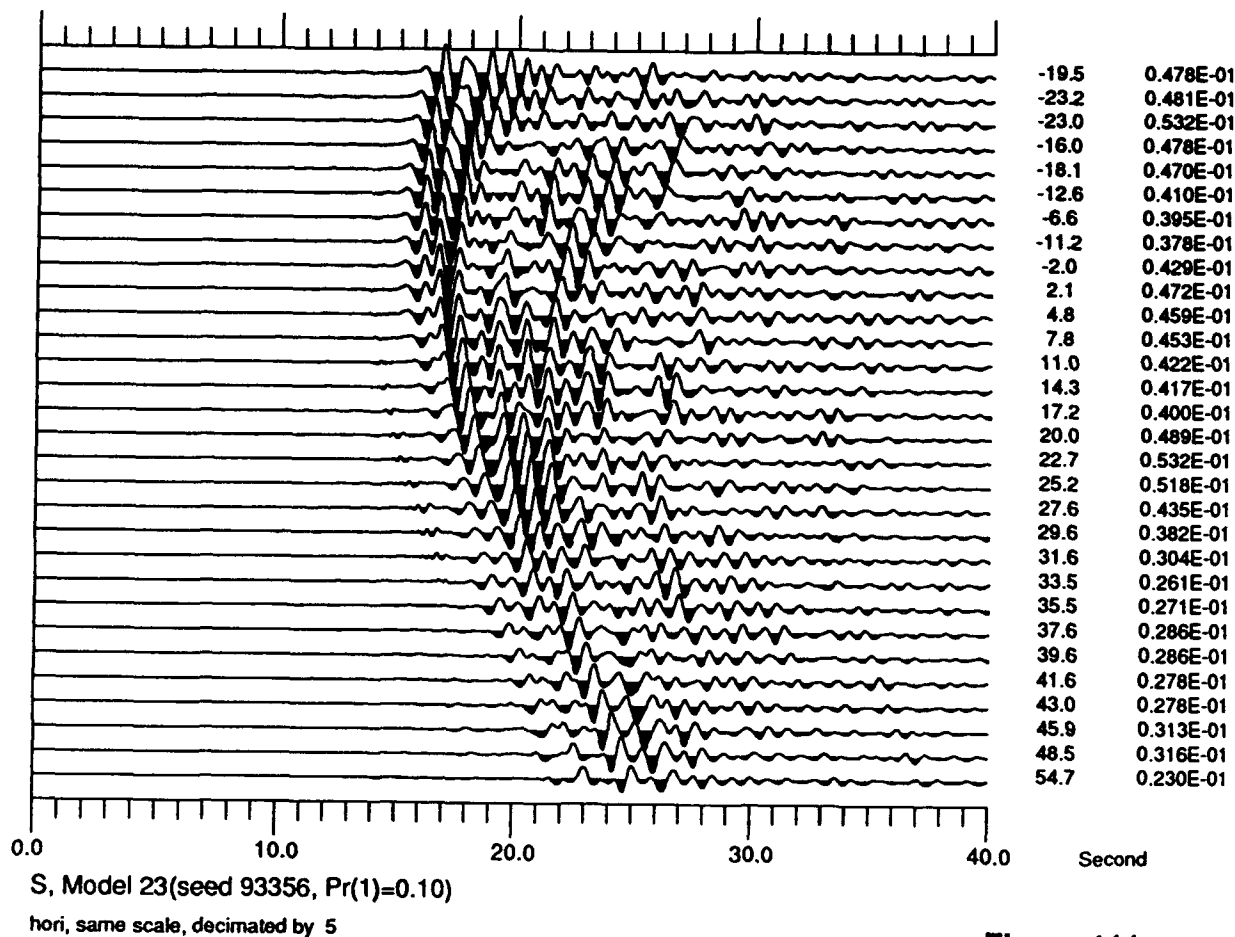
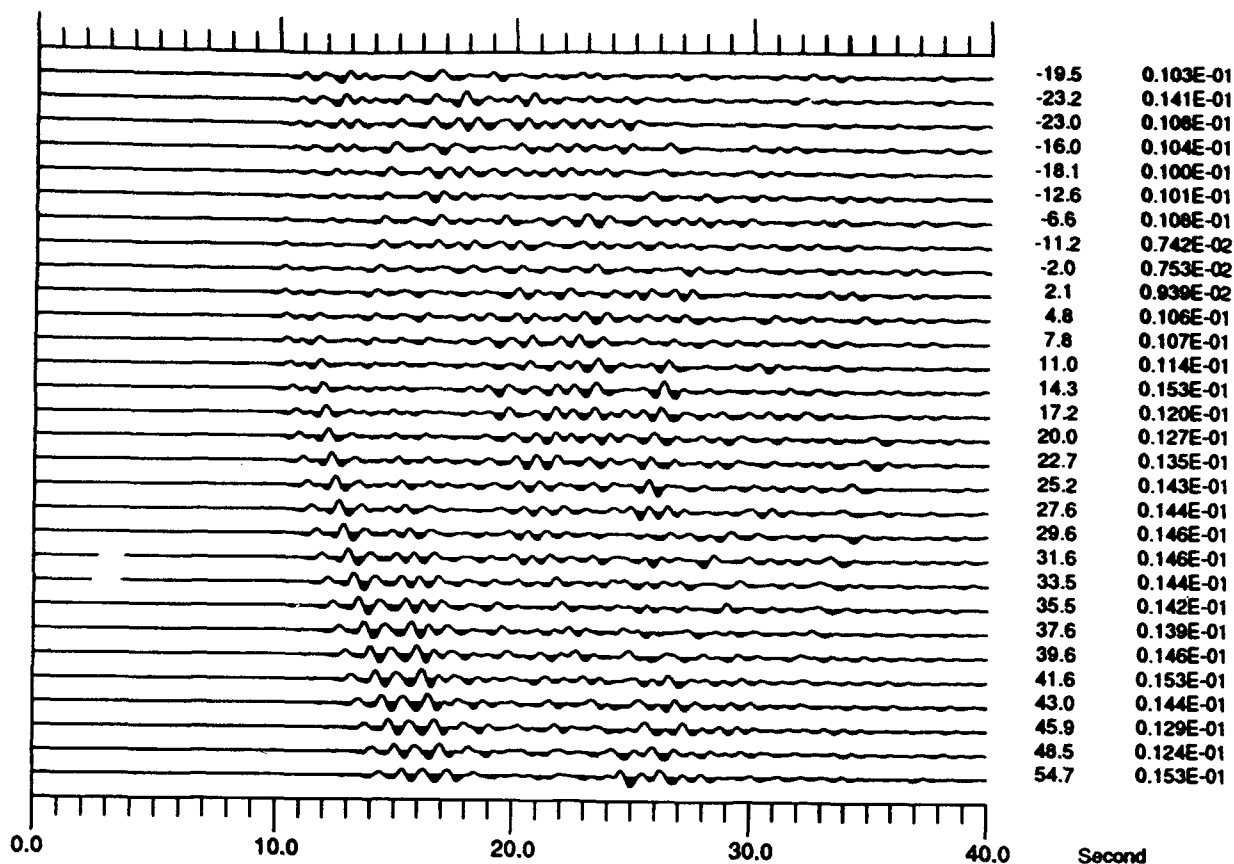


Figure 111

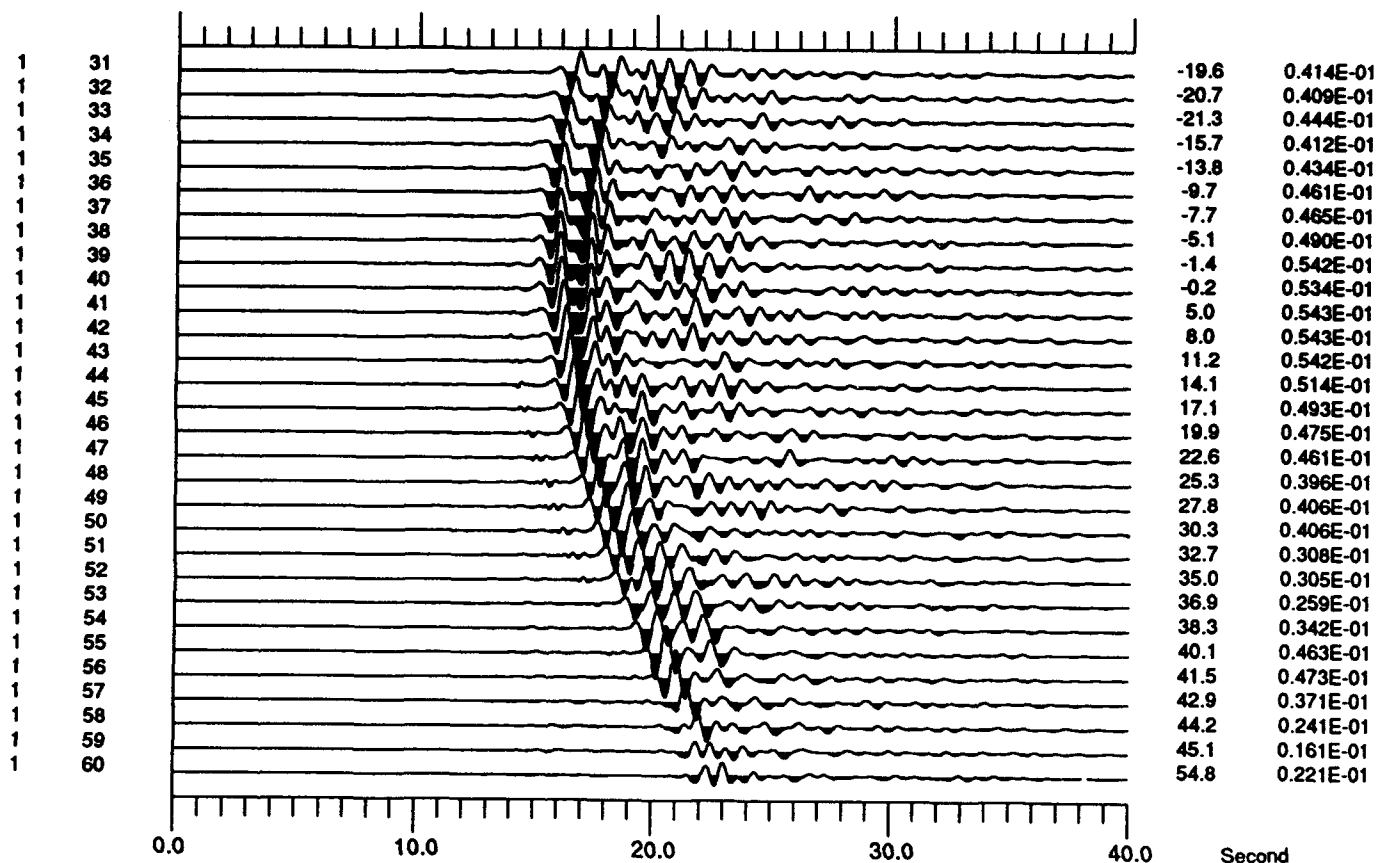
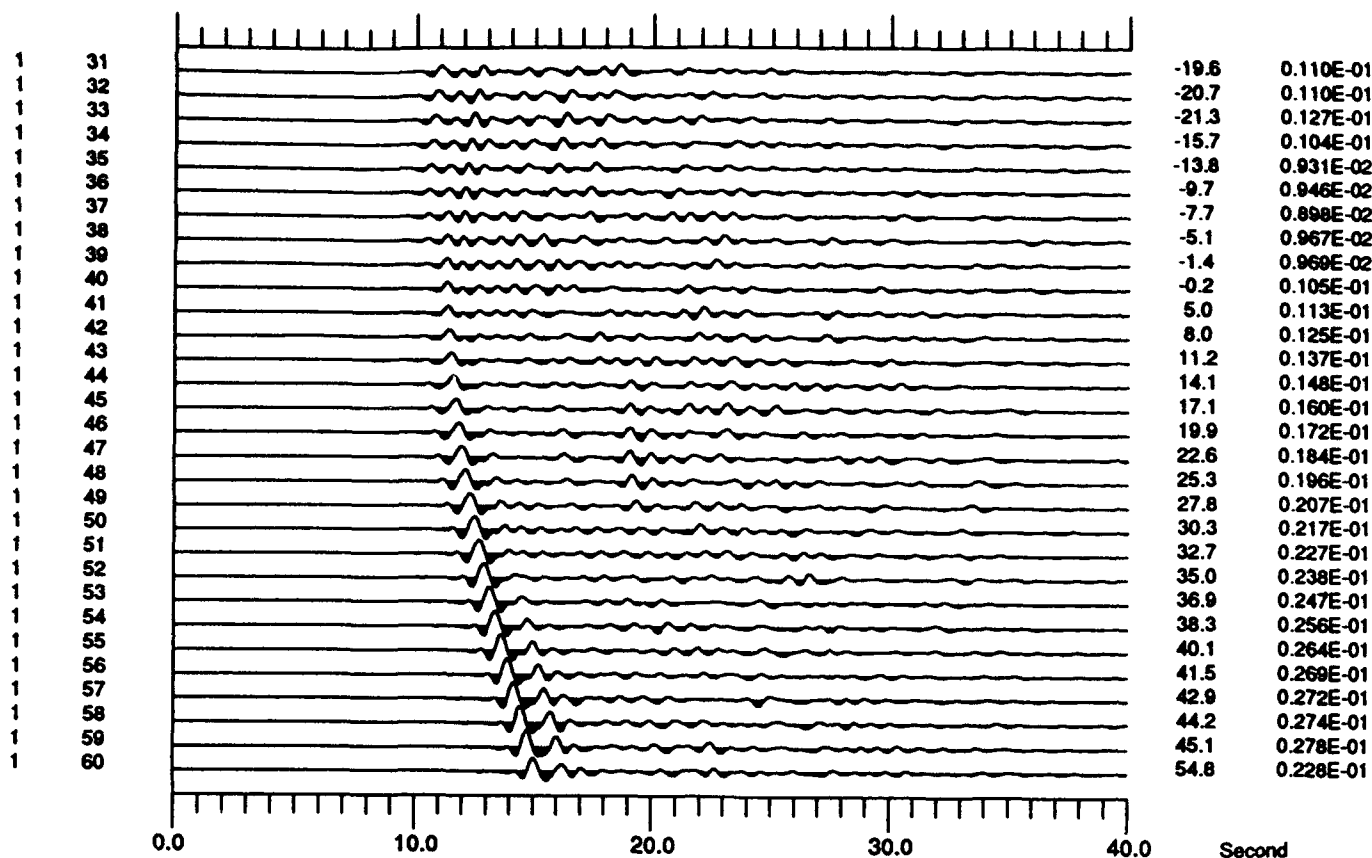
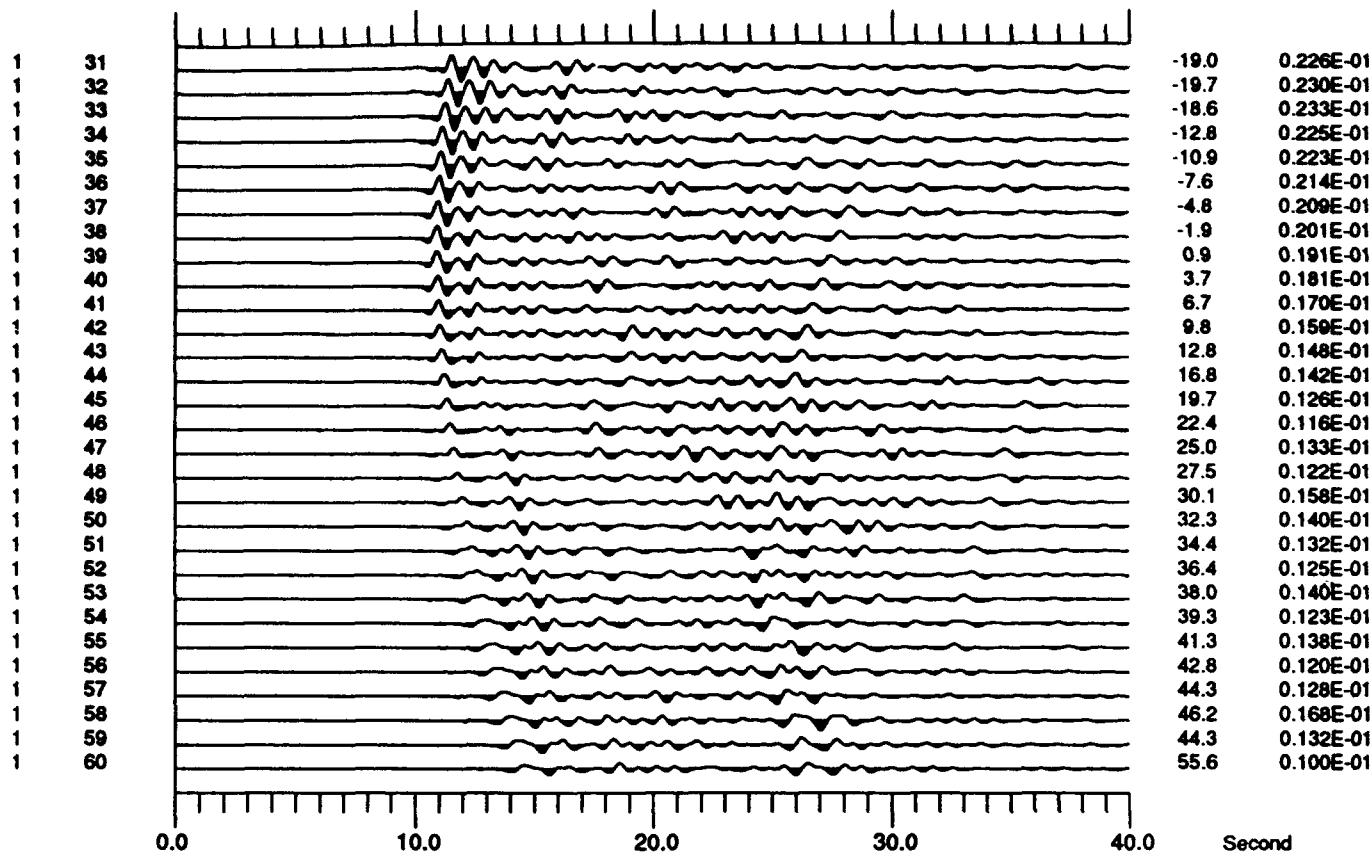
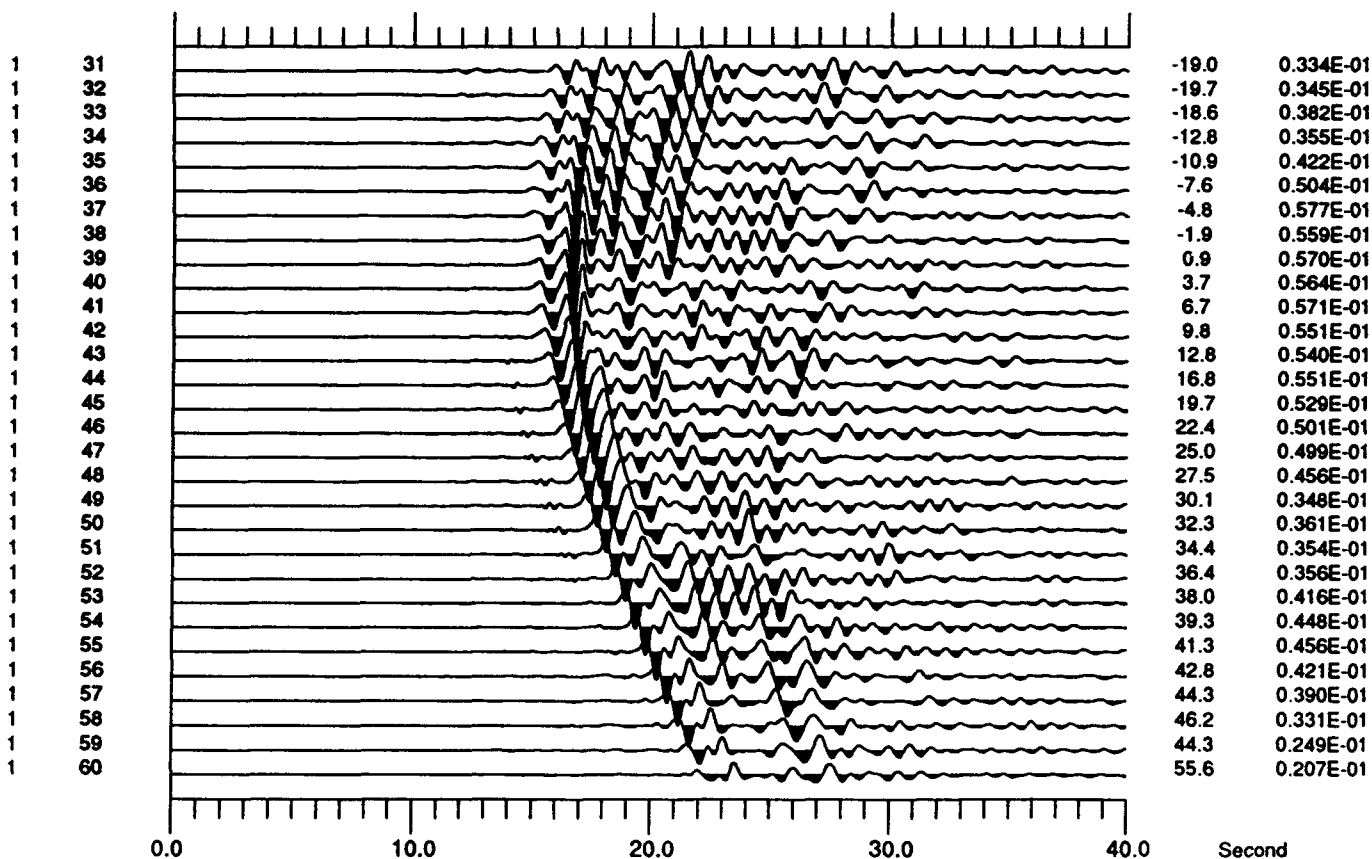


Figure 112



P, Model 32(seed 20333, Pr(1)=0.15)

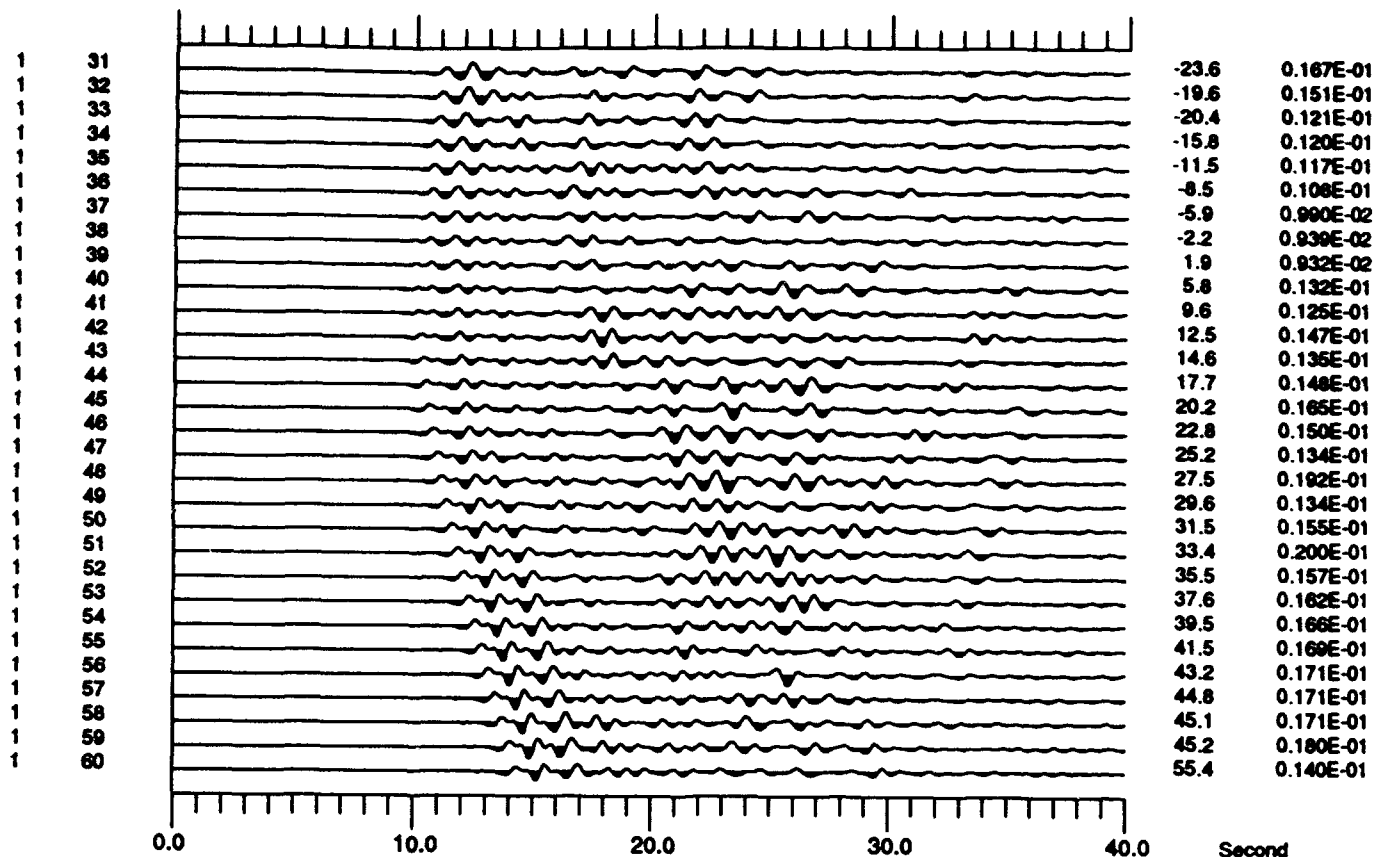
vert, same scale, decimated by 5



S, Model 32(seed 20333, Pr(1)=0.15)

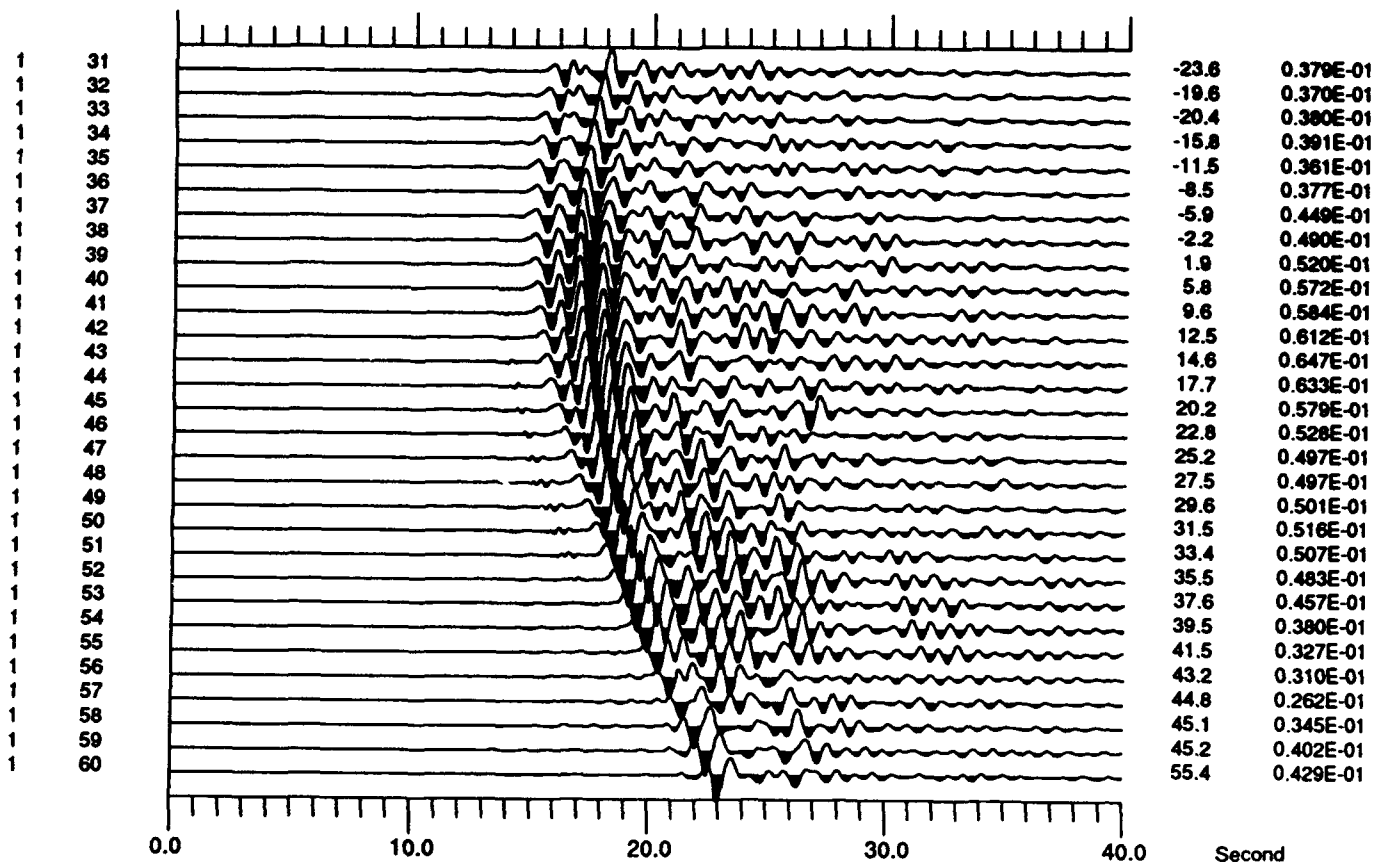
hori, same scale, decimated by 5

Figure 113



P, Model 33(seed 86016, Pr(1)=0.15)

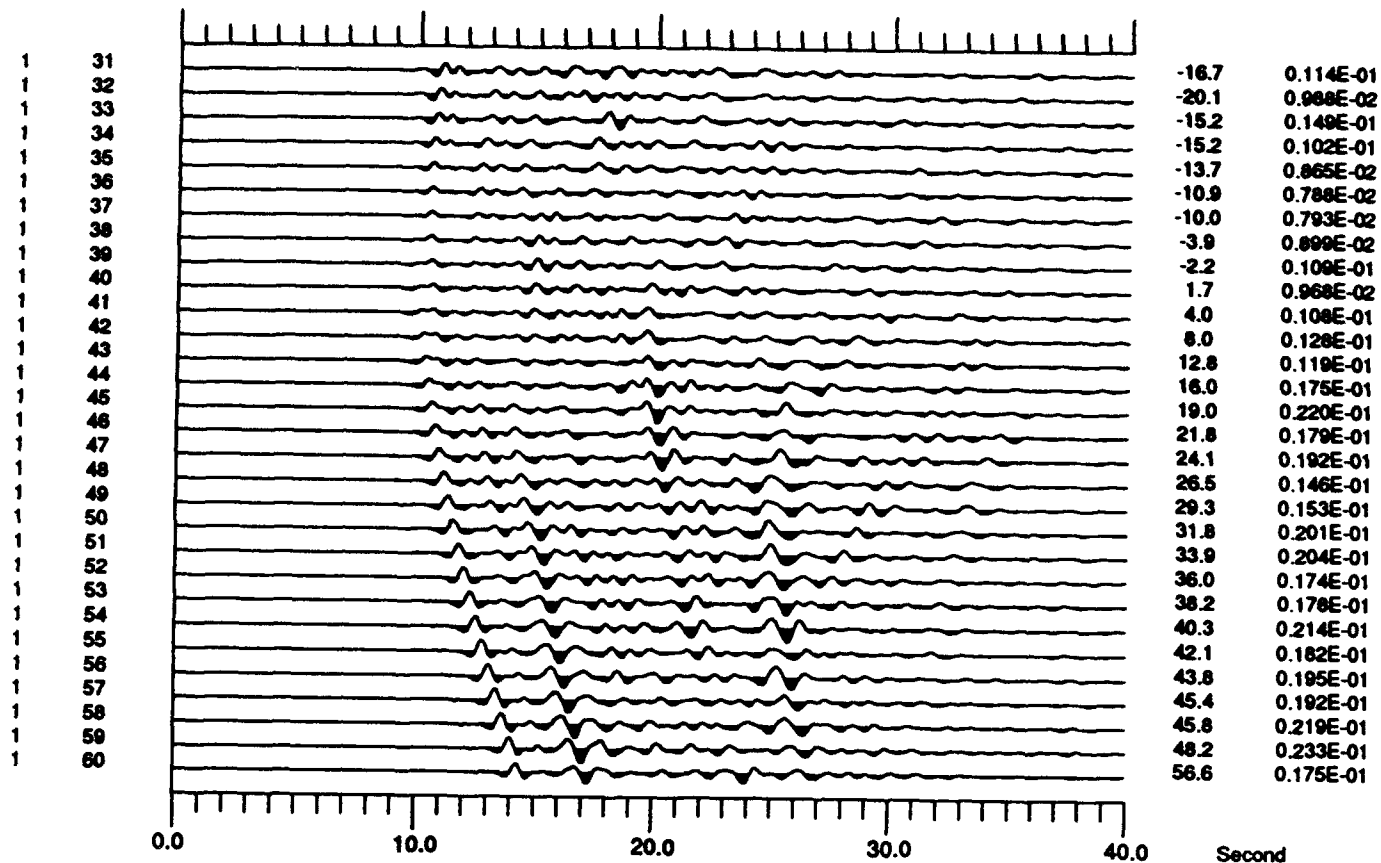
vert, same scale, decimated by 5



S, Model 33(seed 86016, Pr(1)=0.15)

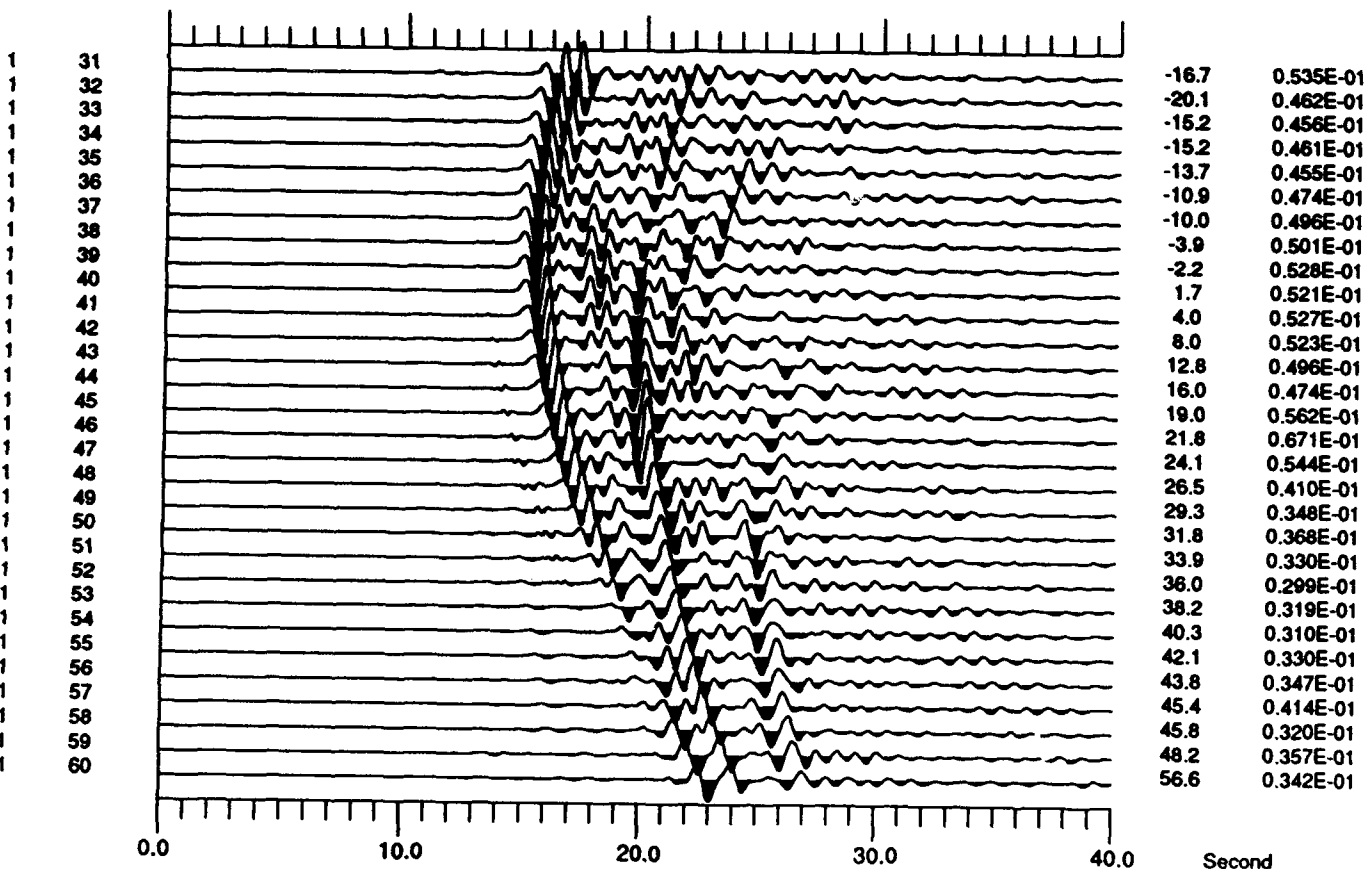
hori, same scale, decimated by 5

Figure 114



P, Model 41(seed 93397, Pr(1)=0.20)

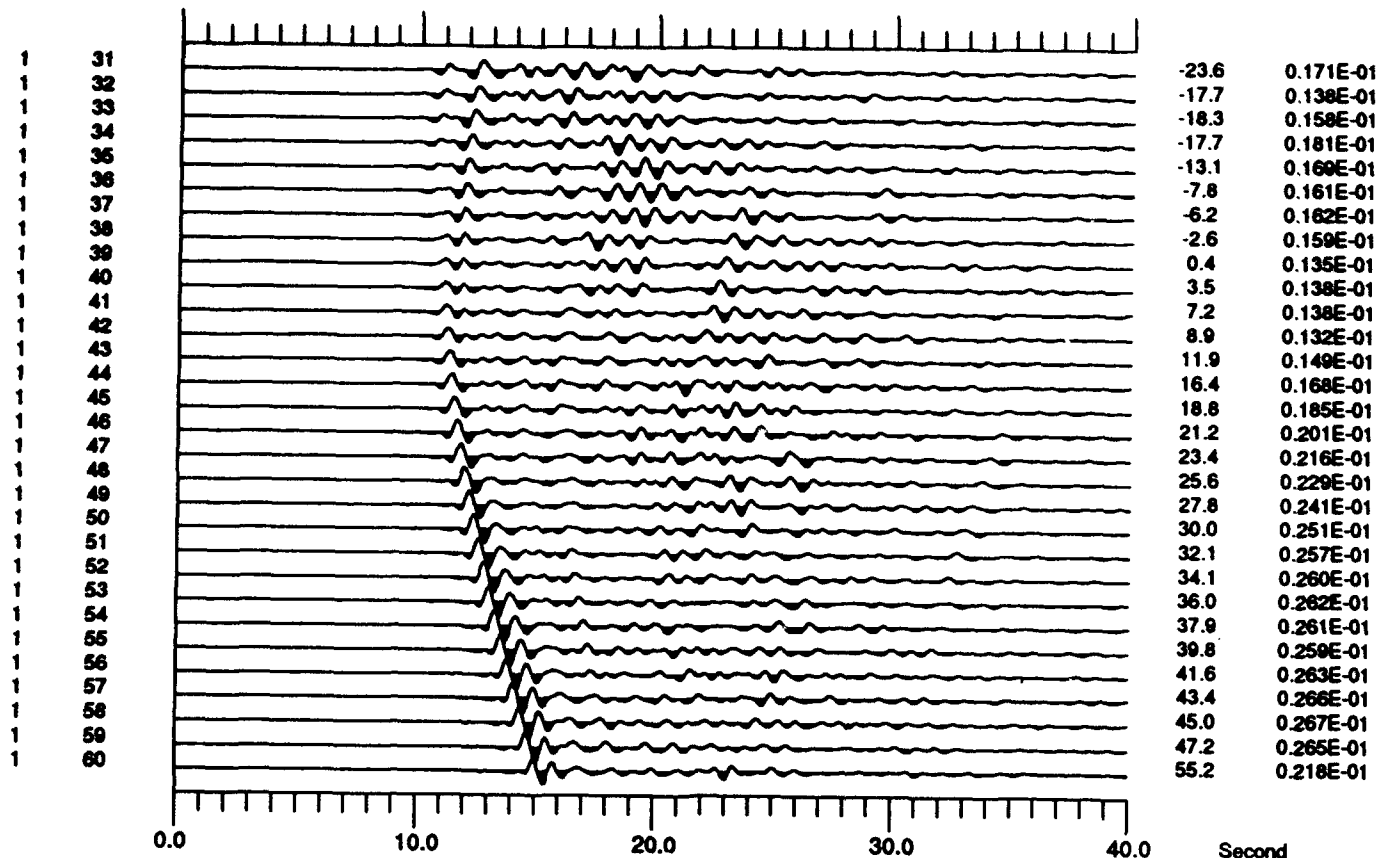
vert, same scale, decimated by 5



S, Model 41(seed 93397, Pr(1)=0.20)

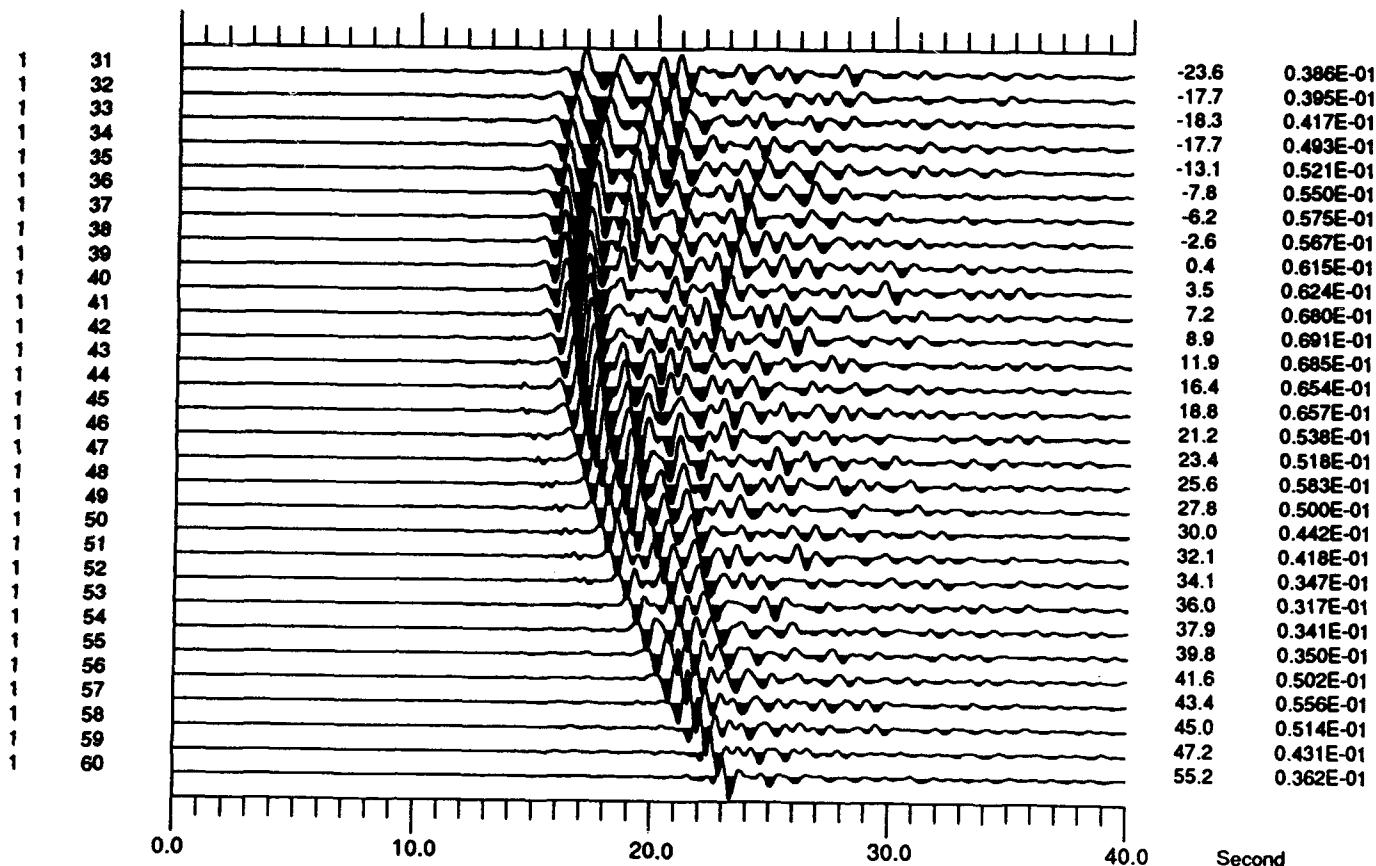
hori, same scale, decimated by 5

Figure 115



P, Model 42(seed 93407, Pr(1)=0.20)

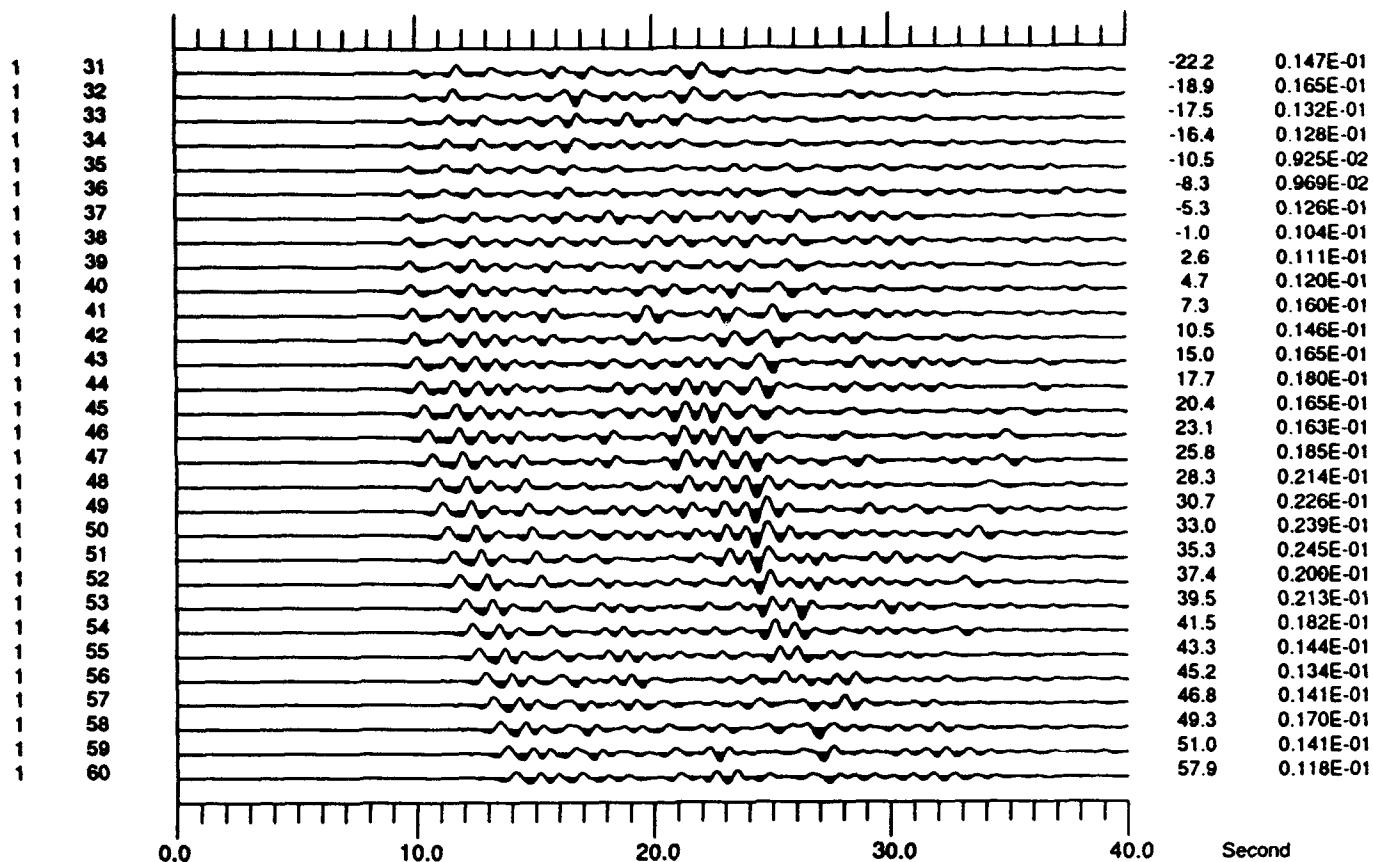
vert, same scale, decimated by 5



S, Model 42(seed 93407, Pr(1)=0.20)

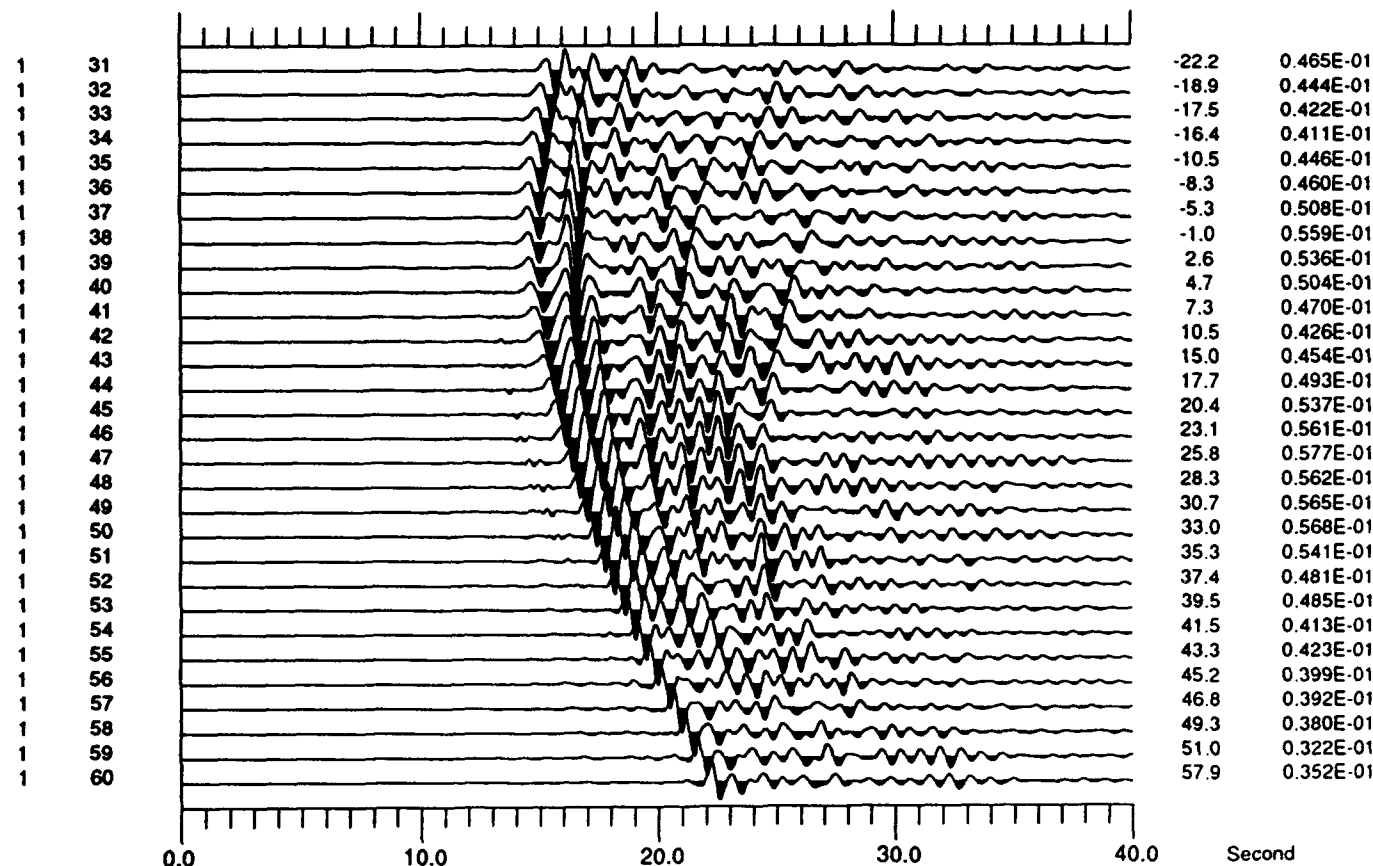
hori, same scale, decimated by 5

Figure 116



P, Model 43(seed 12345, Pr(1)=0.20)

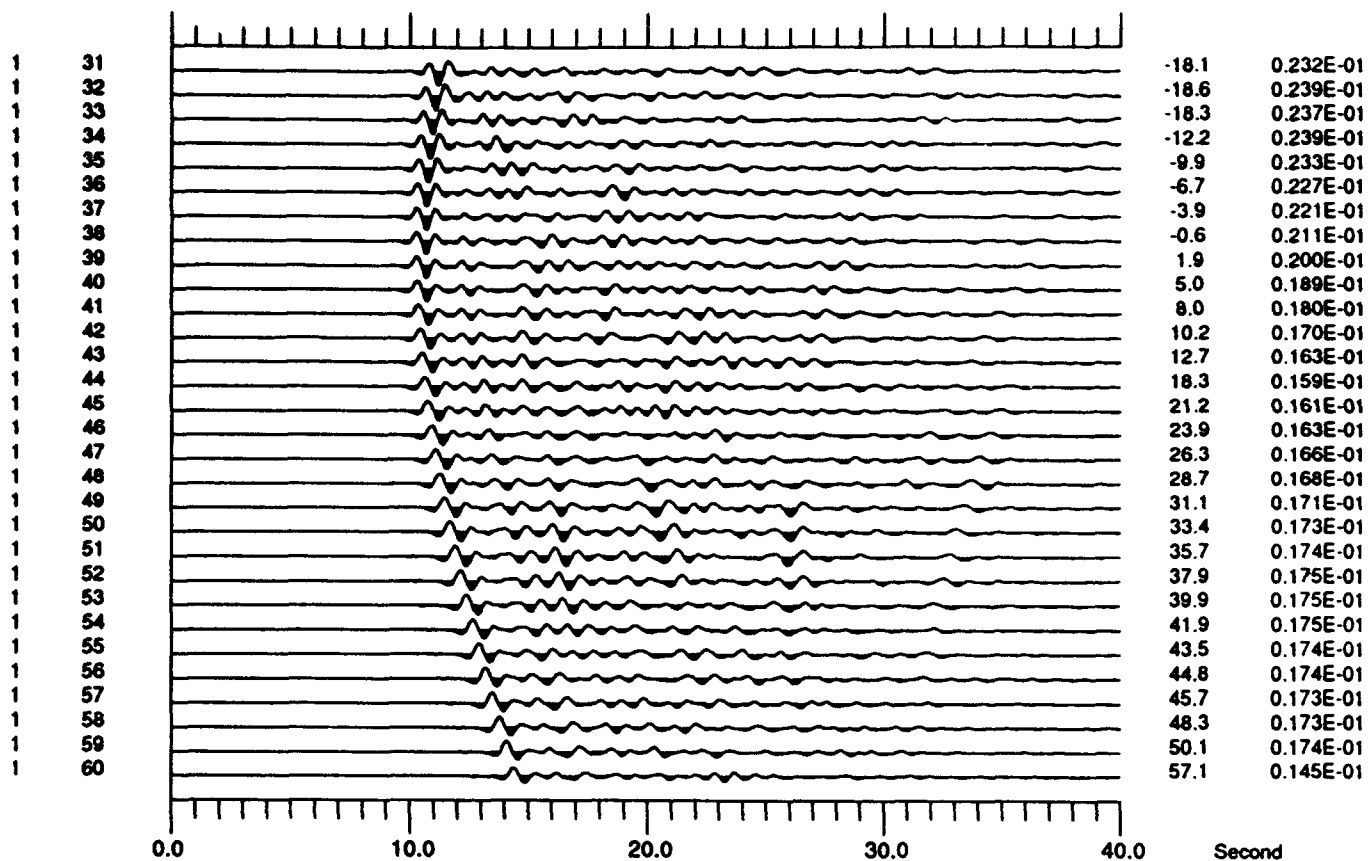
vert, same scale, decimated by 5



S, Model 43(seed 12345, Pr(1)=0.20)

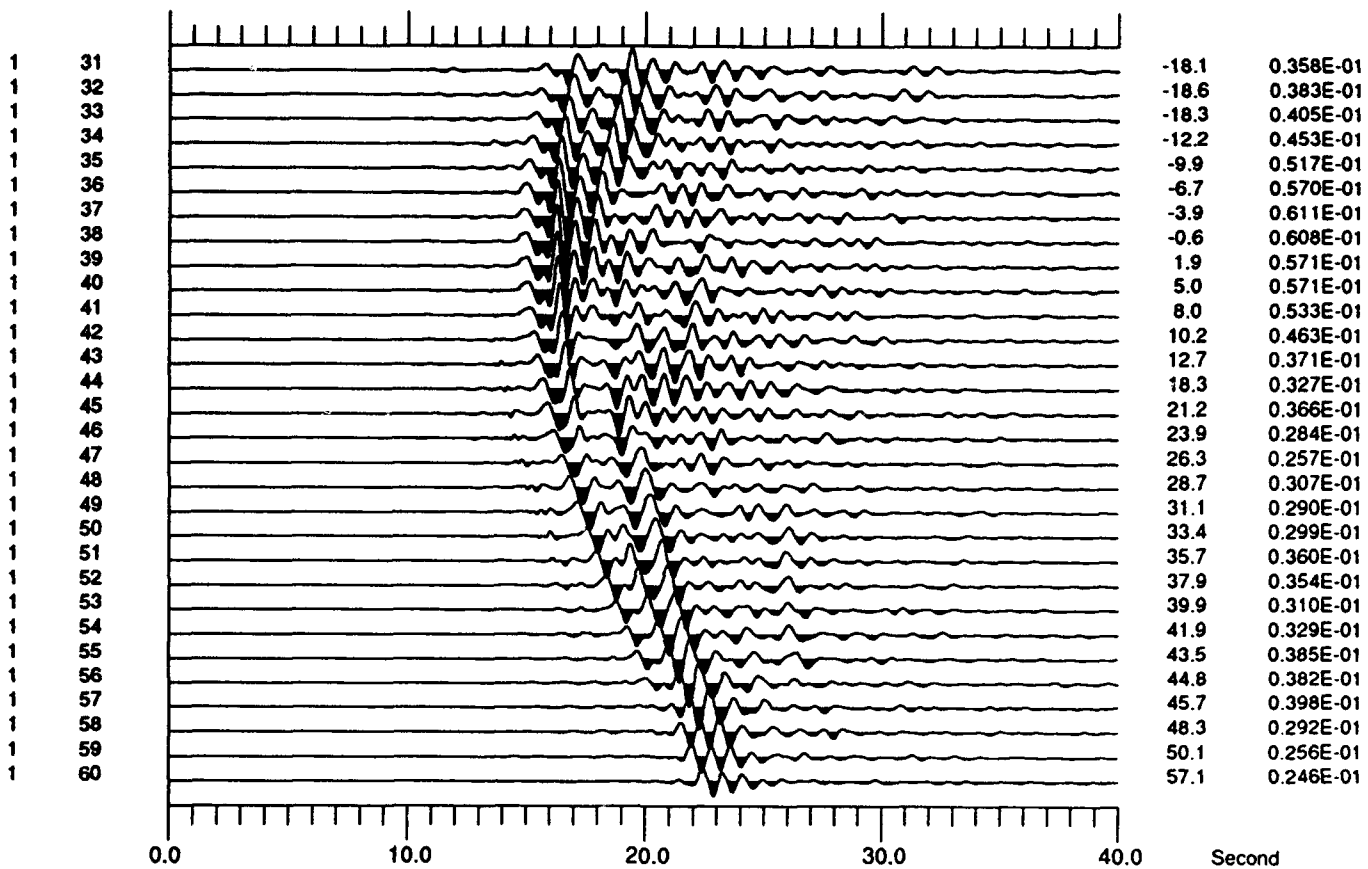
hori, same scale, decimated by 5

Figure 117



P, Model 51(seed 21691, Pr(1)=0.25)

vert, same scale, decimated by 5



S, Model 51(seed 21691, Pr(1)=0.25)

hori, same scale, decimated by 5

Figure 118

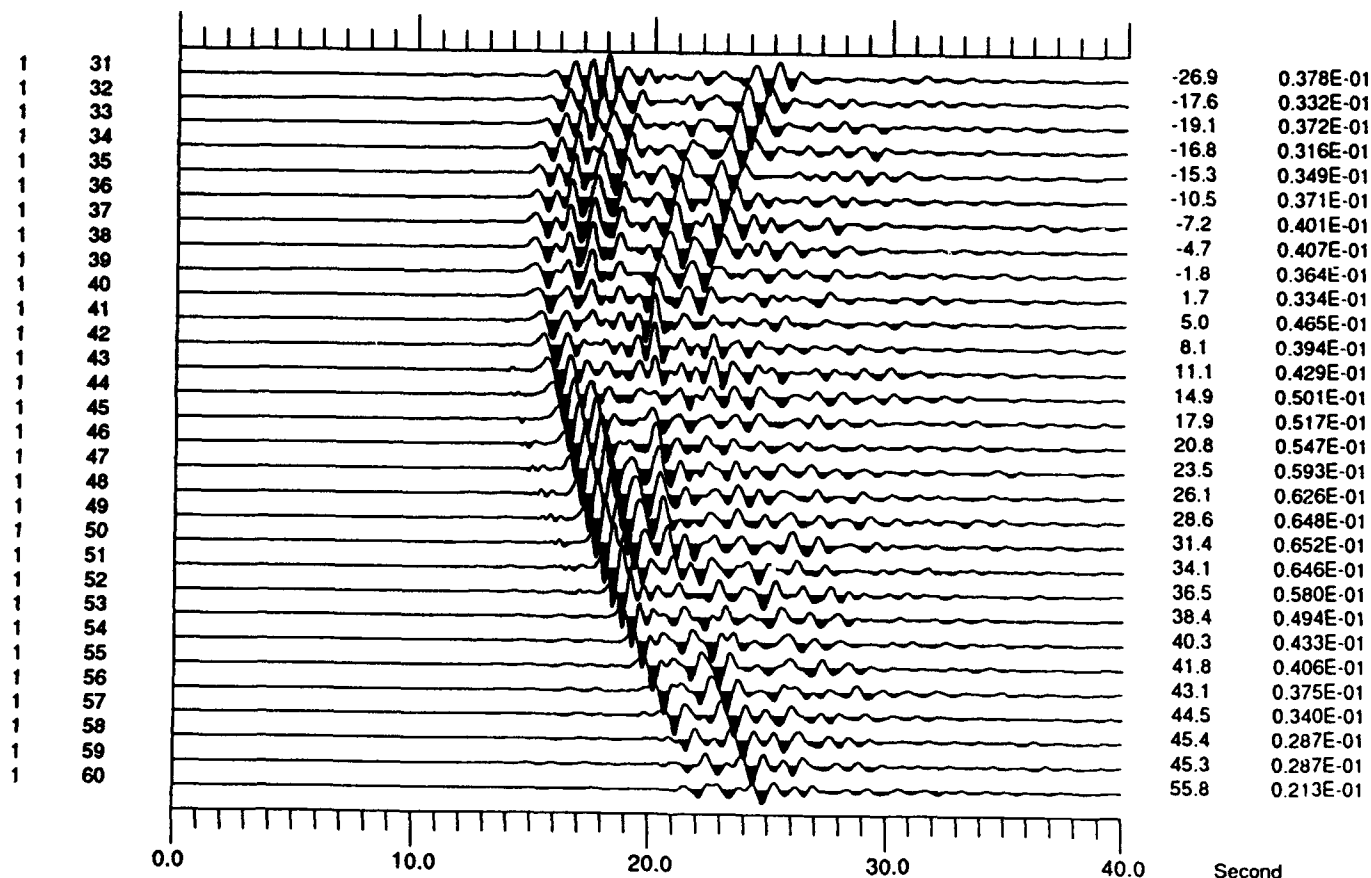
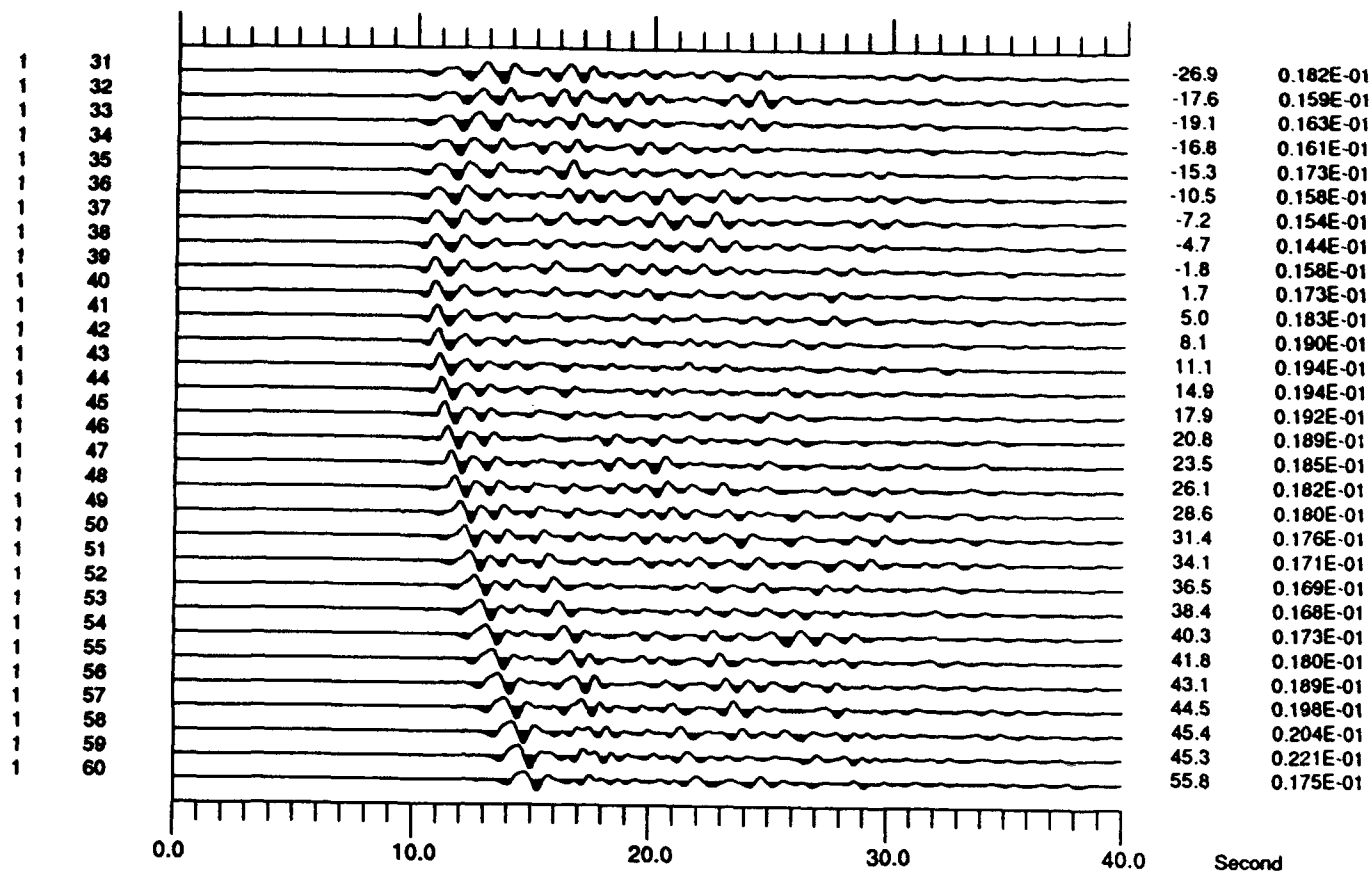
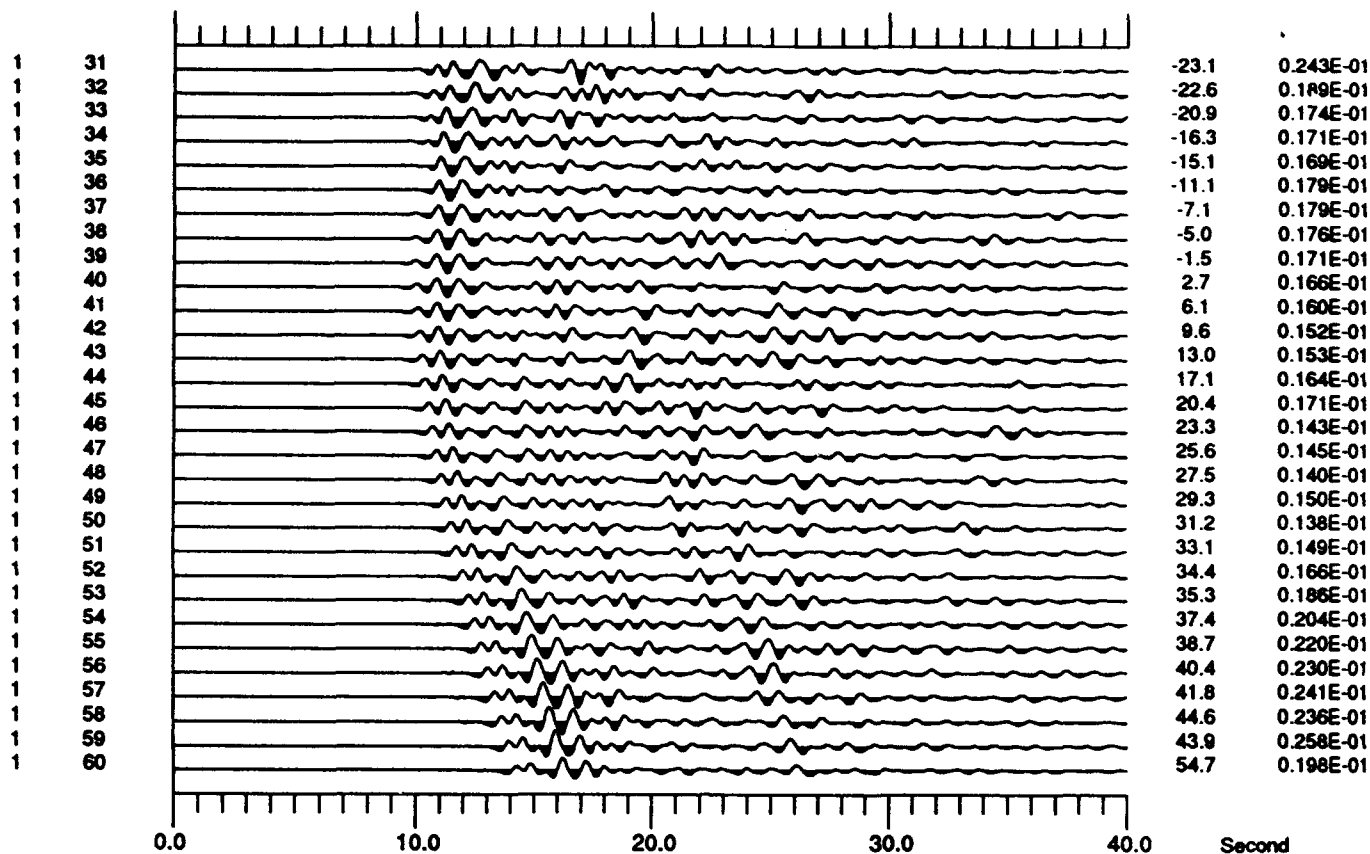
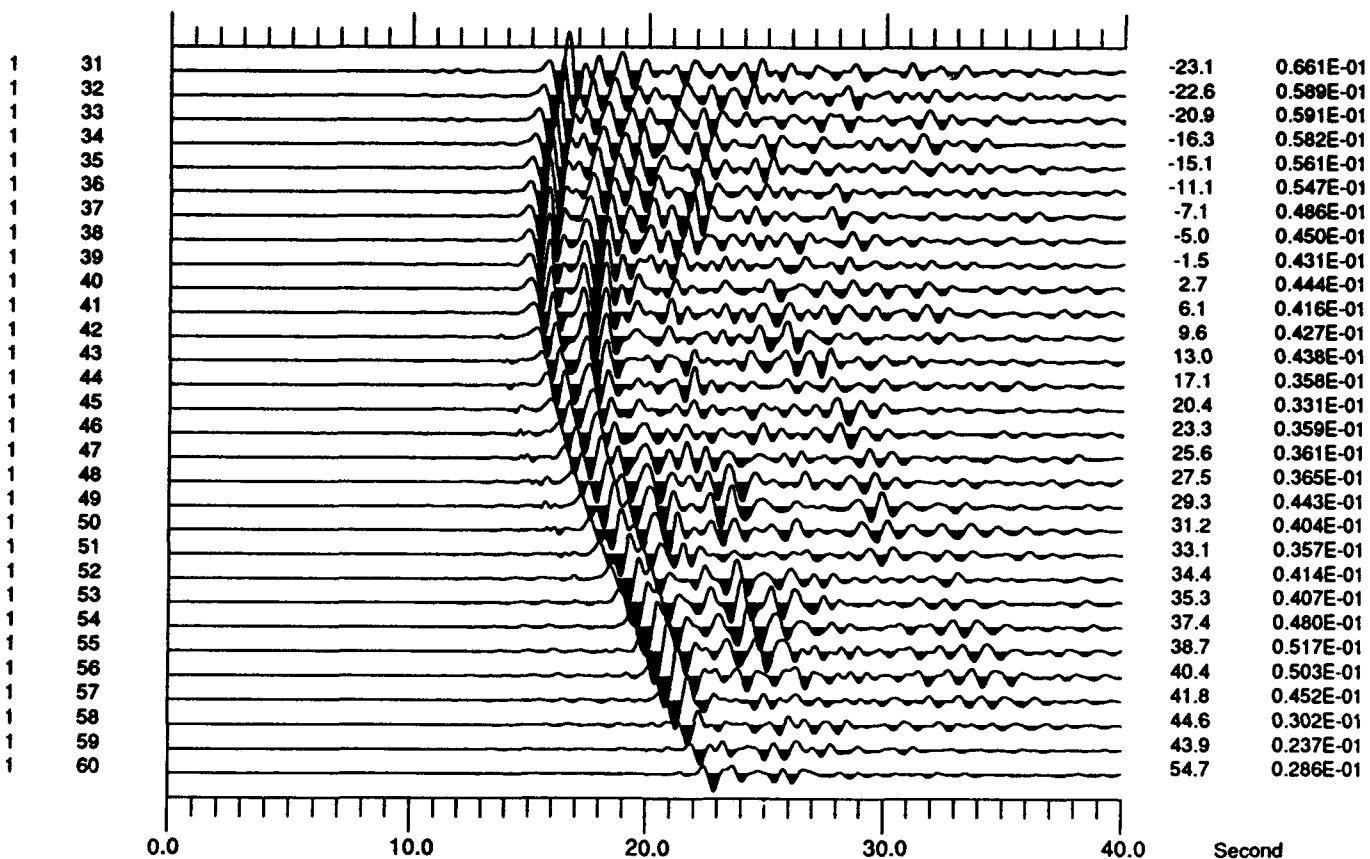


Figure 119



P, Model 53(seed 86037, Pr(1)=0.25)

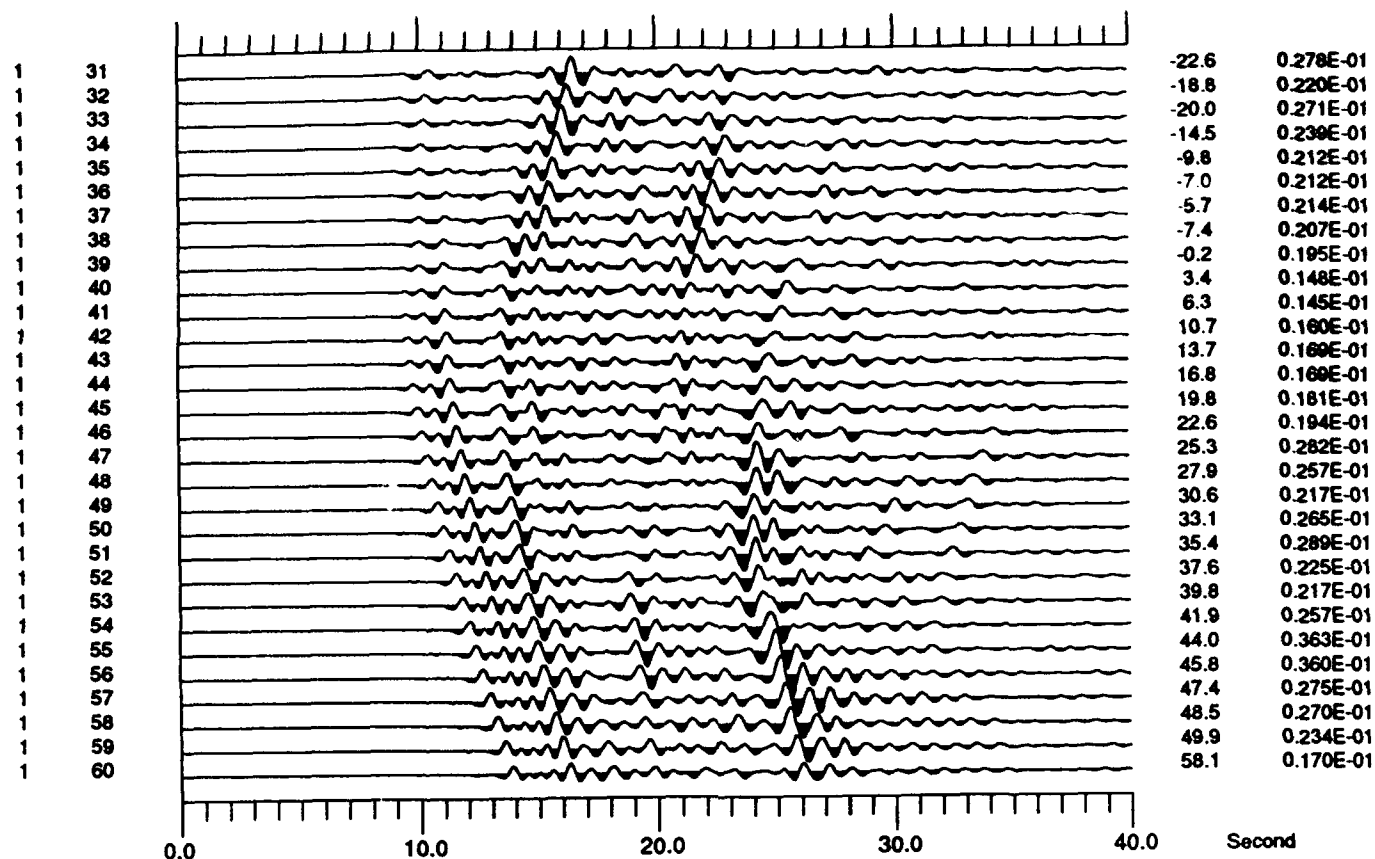
vert, same scale, decimated by 5



S, Model 53(seed 86037, Pr(1)=0.25)

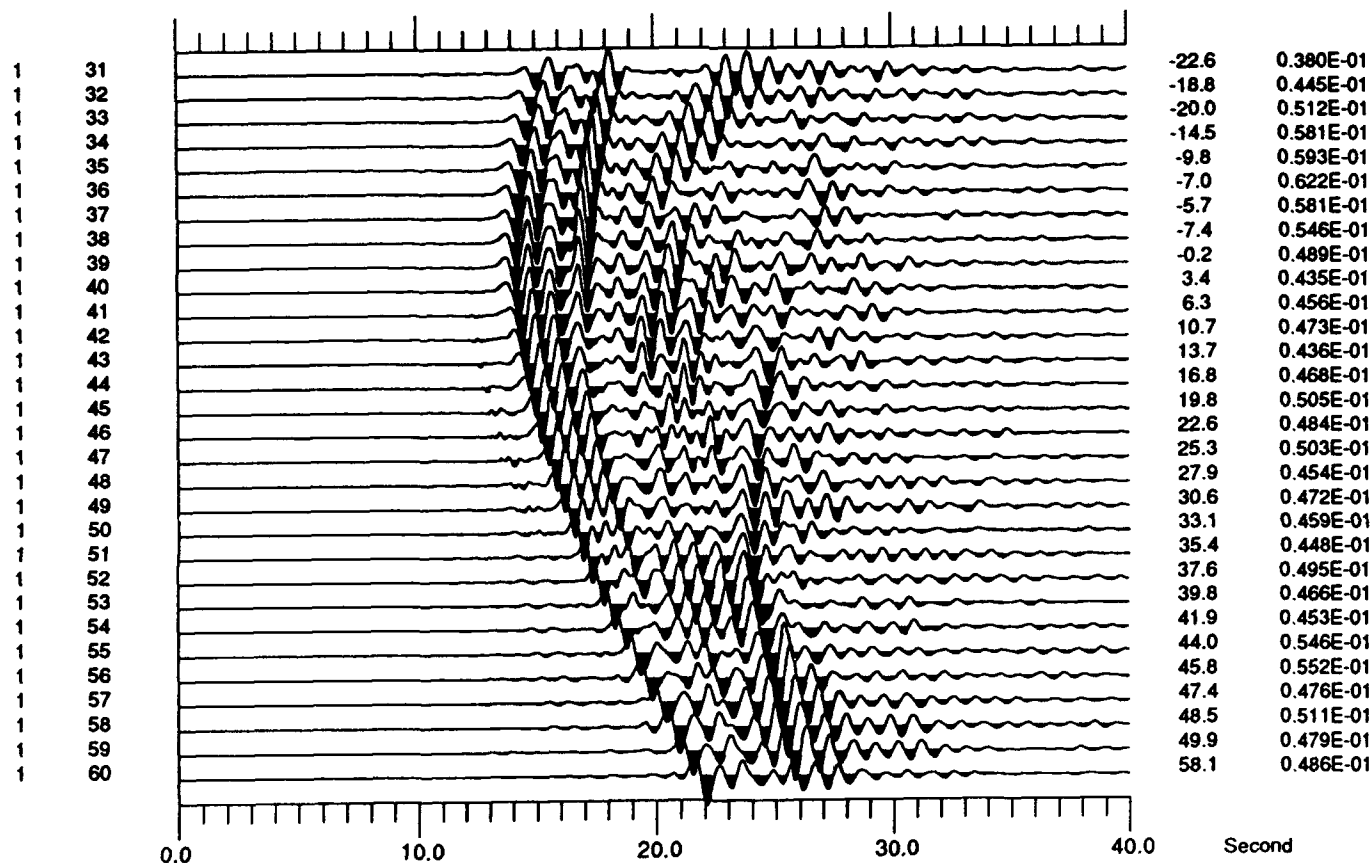
hori, same scale, decimated by 5

Figure 120



P, Model 61(seed 93459, Pr(1)=0.30)

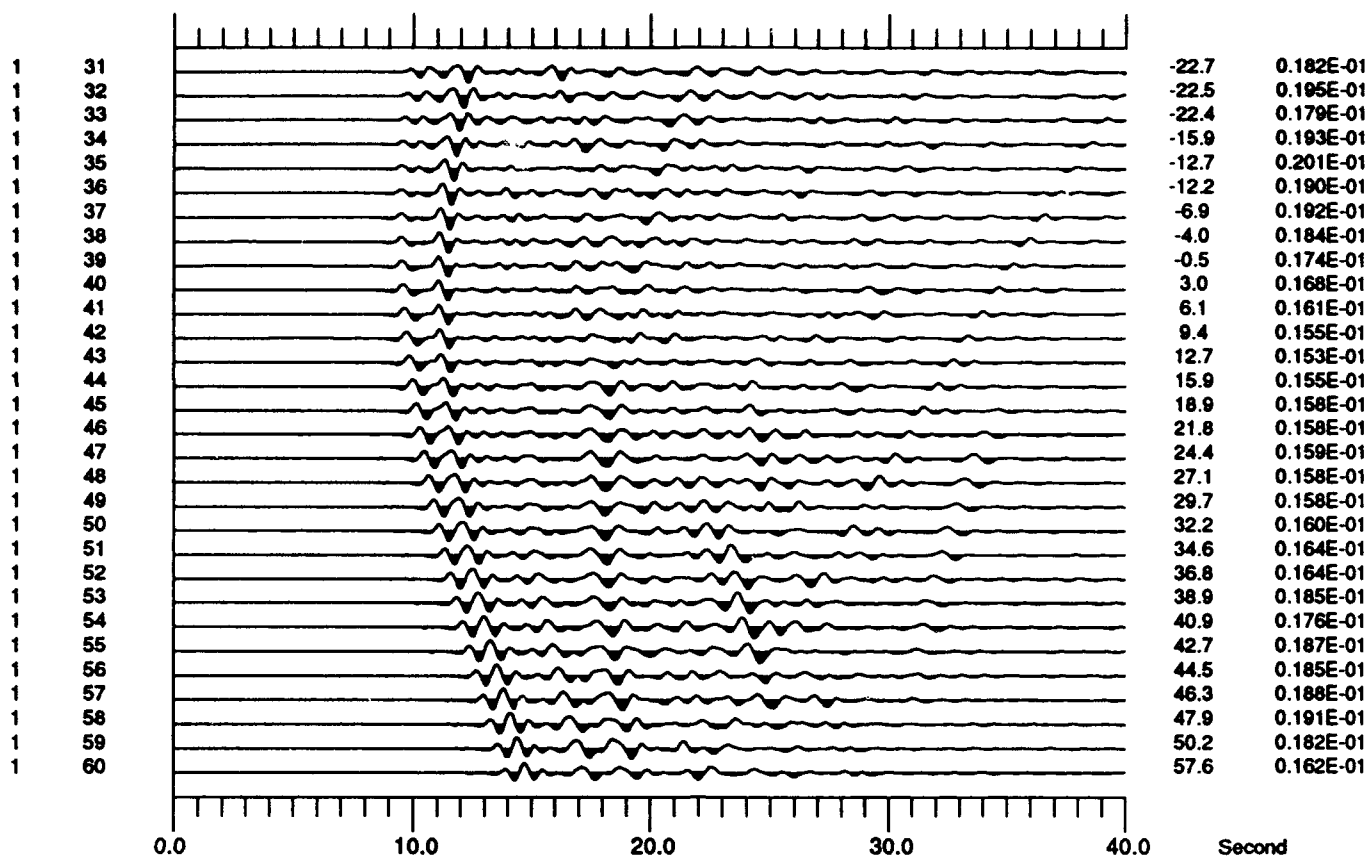
vert, same scale, decimated by 5



S, Model 61(seed 93459, Pr(1)=0.30)

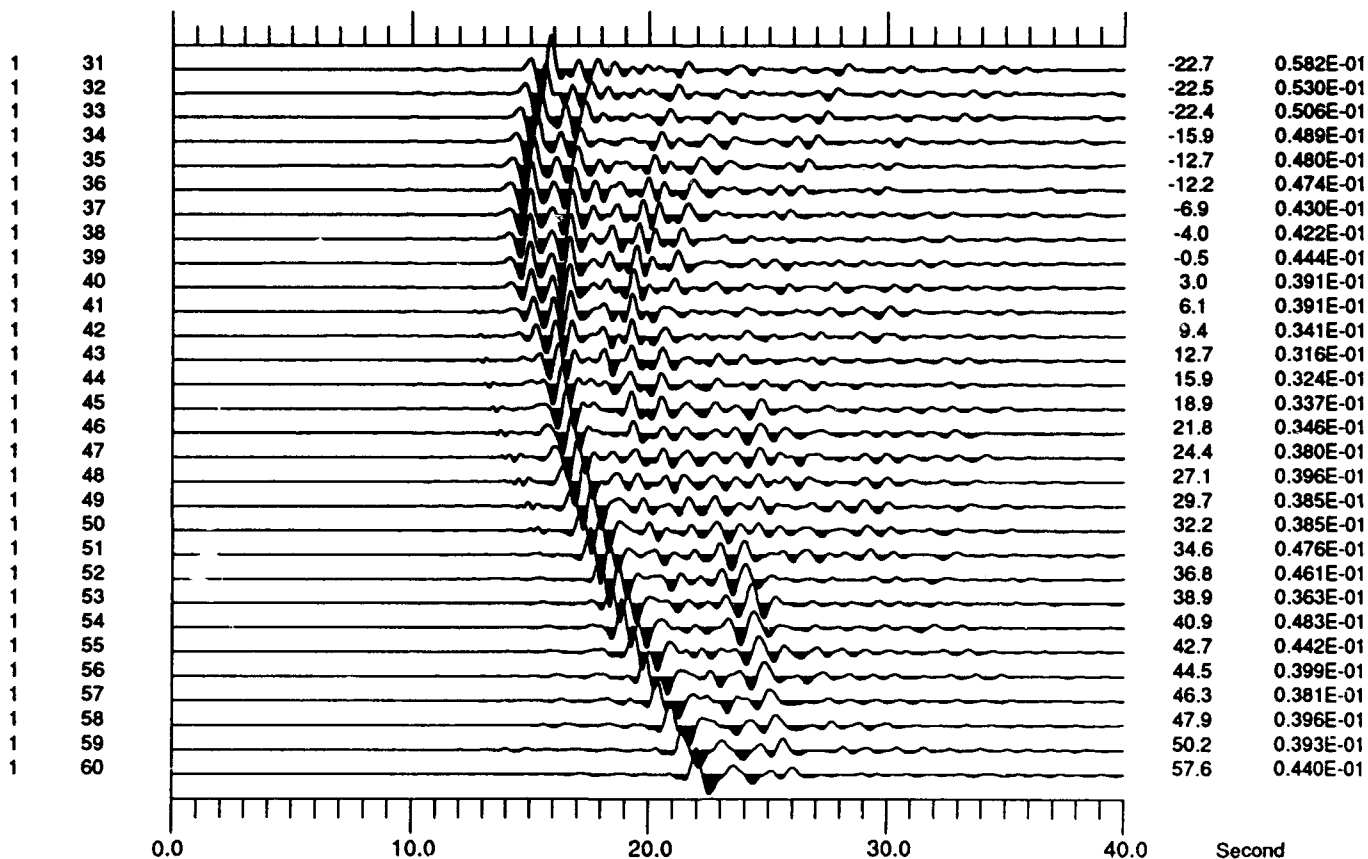
hori, same scale, decimated by 5

Figure 121



P, Model 62(seed 93468, Pr(1)=0.30)

vert, same scale, decimated by 5



S, Model 62(seed 93468, Pr(1)=0.30)

hori, same scale, decimated by 5

Figure 122

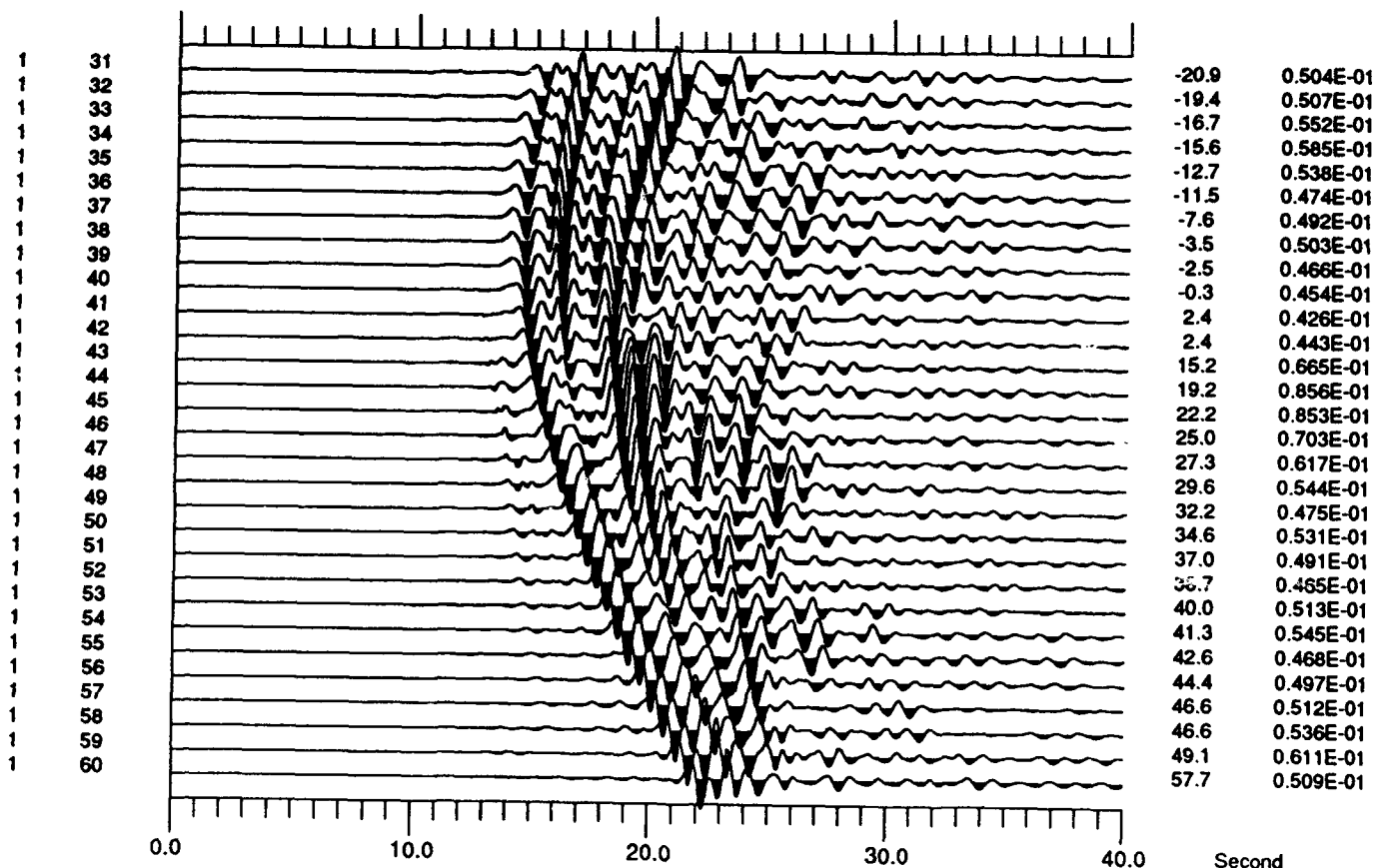
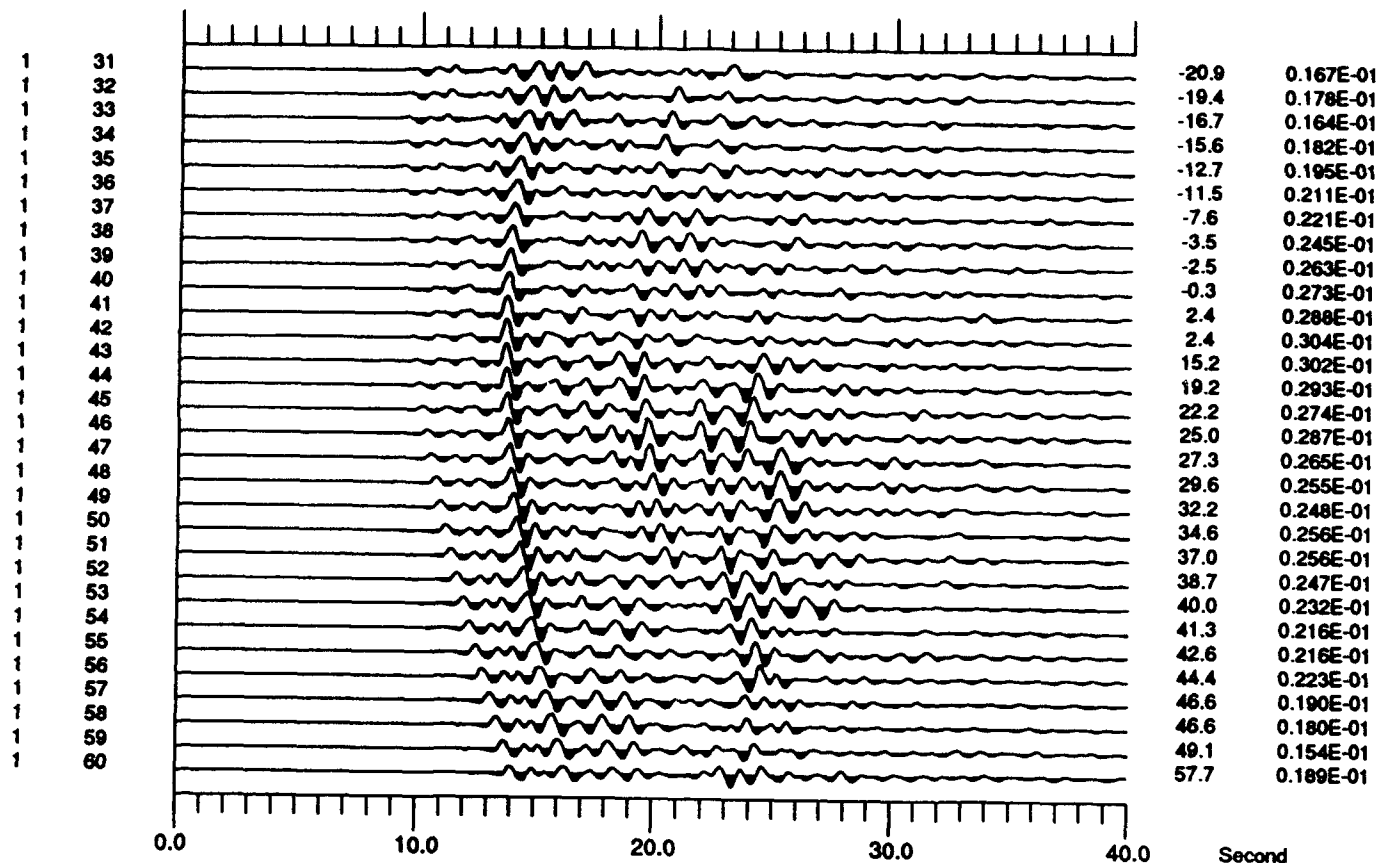
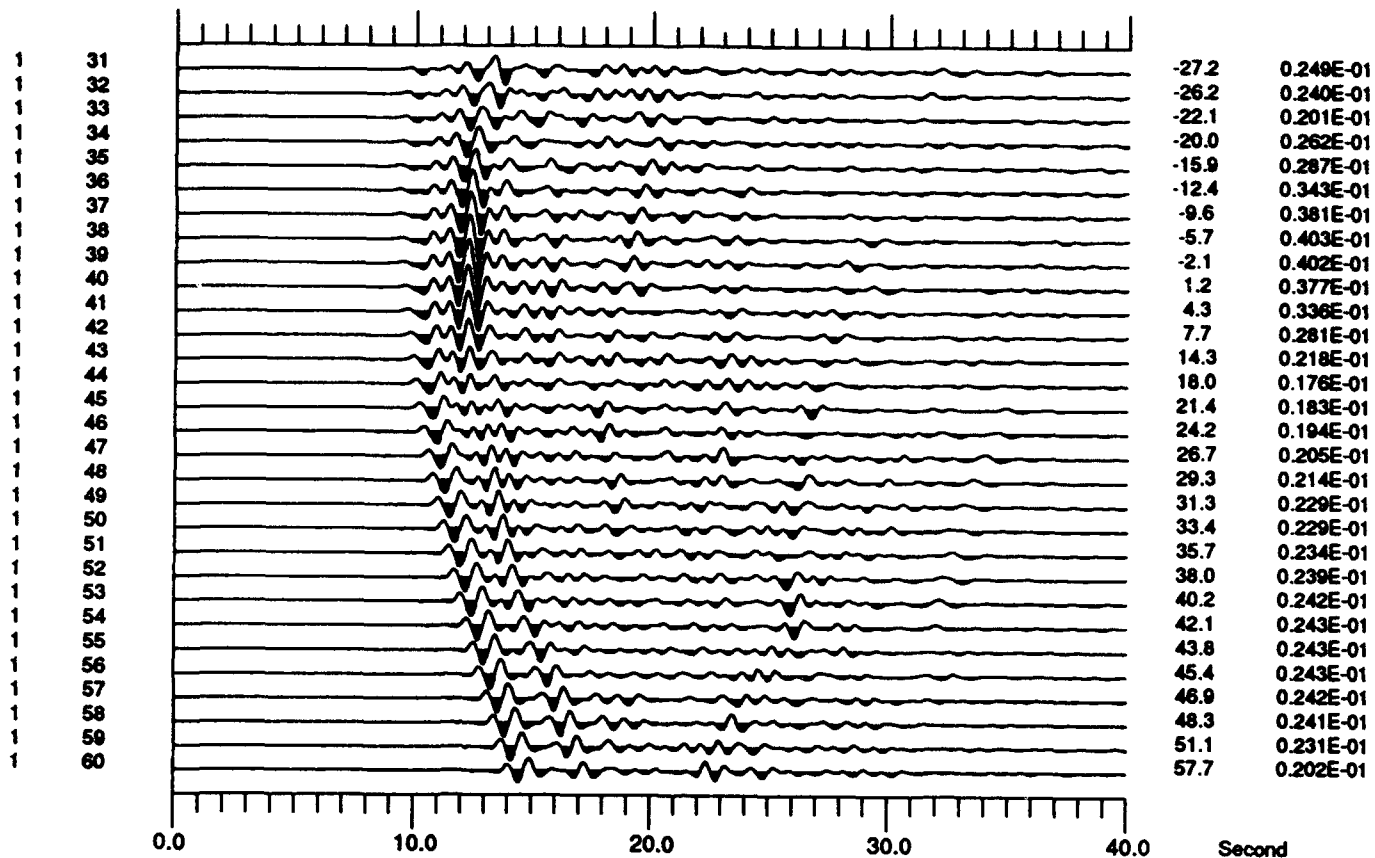
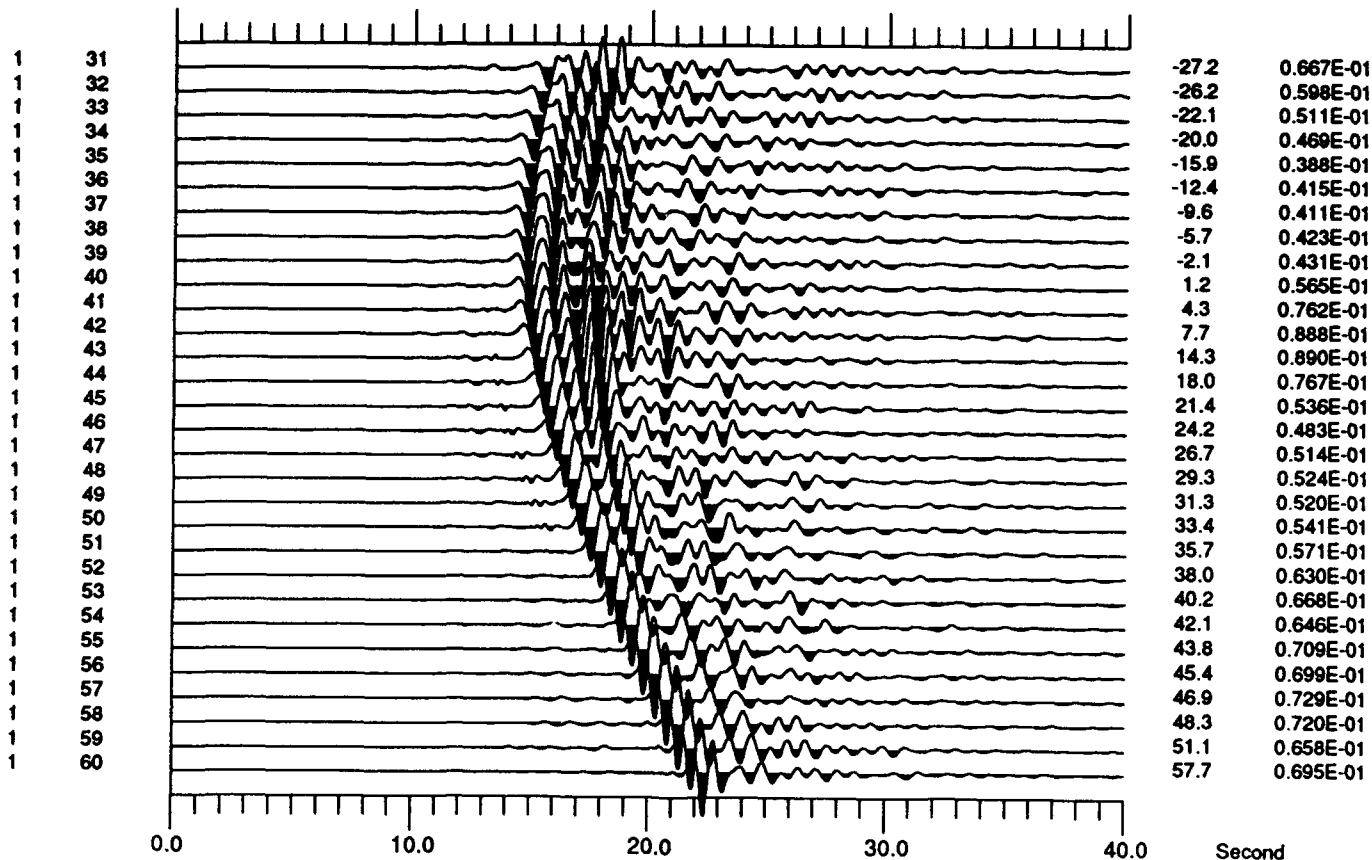


Figure 123



P, Model 64(seed 55473, Pr(1)=0.32)

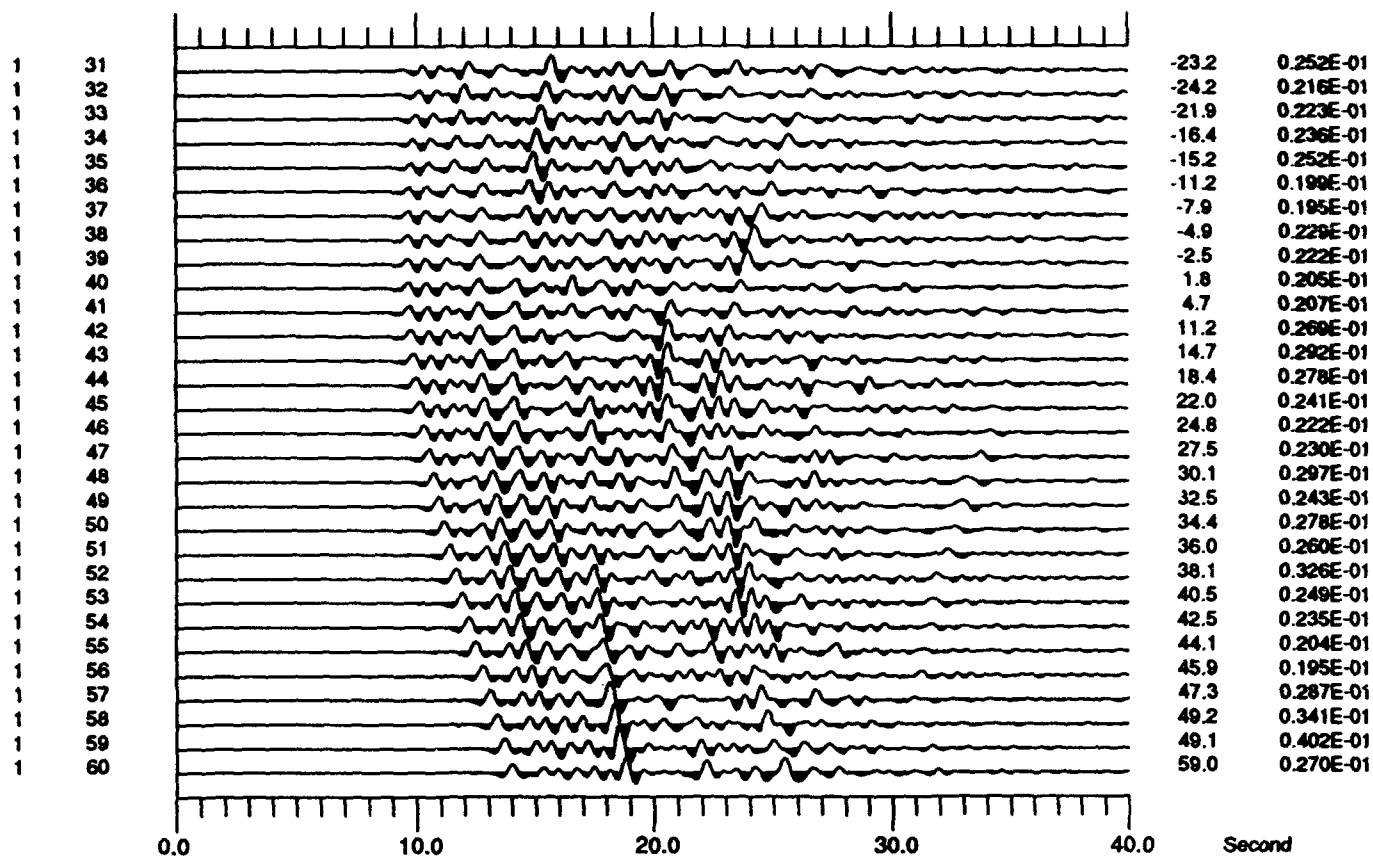
vert, same scale, decimated by 5



S, Model 64(seed 55473, Pr(1)=0.32)

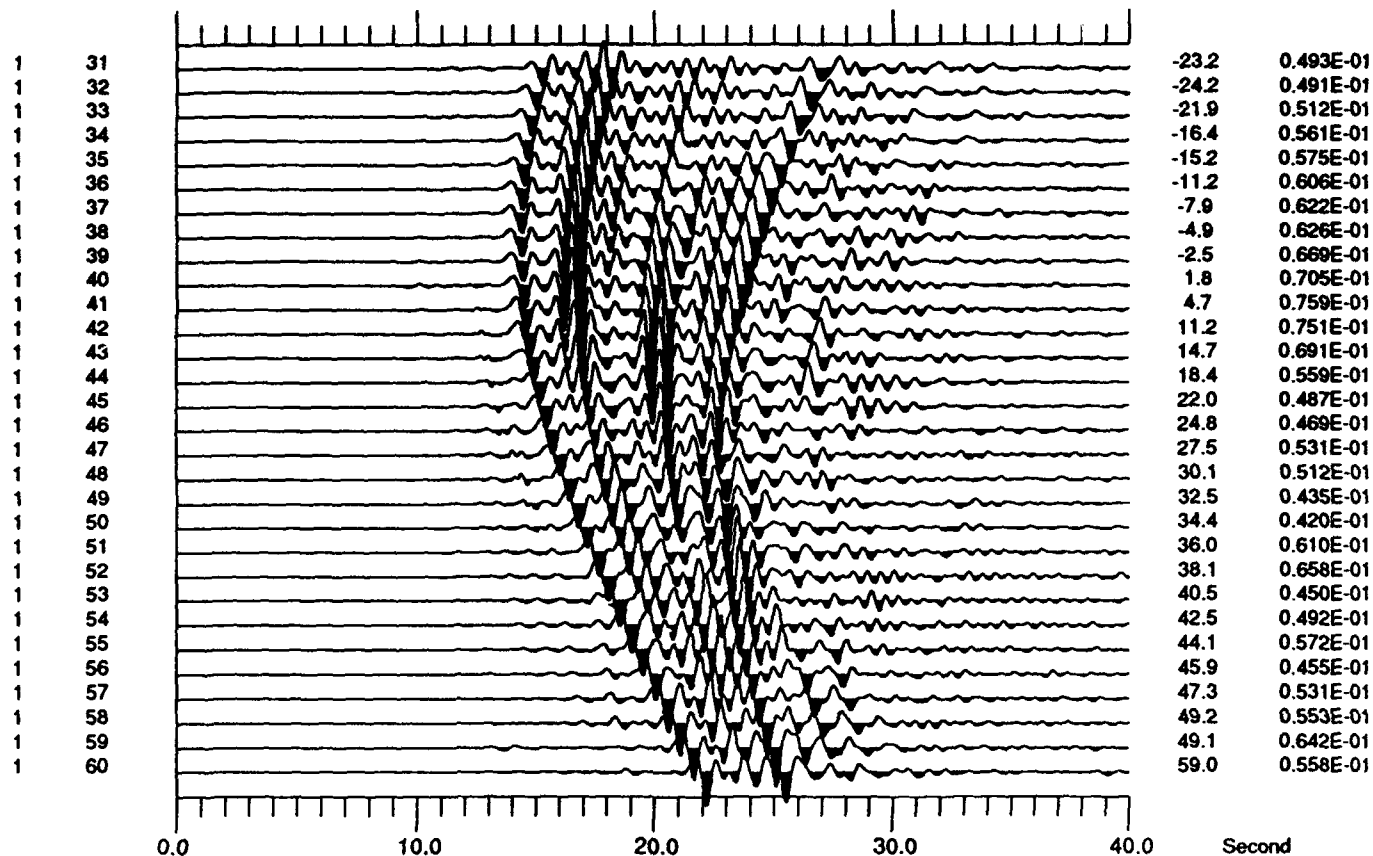
hori, same scale, decimated by 5

Figure 124



P, Model 65(seed 55499, Pr(1)=0.32)

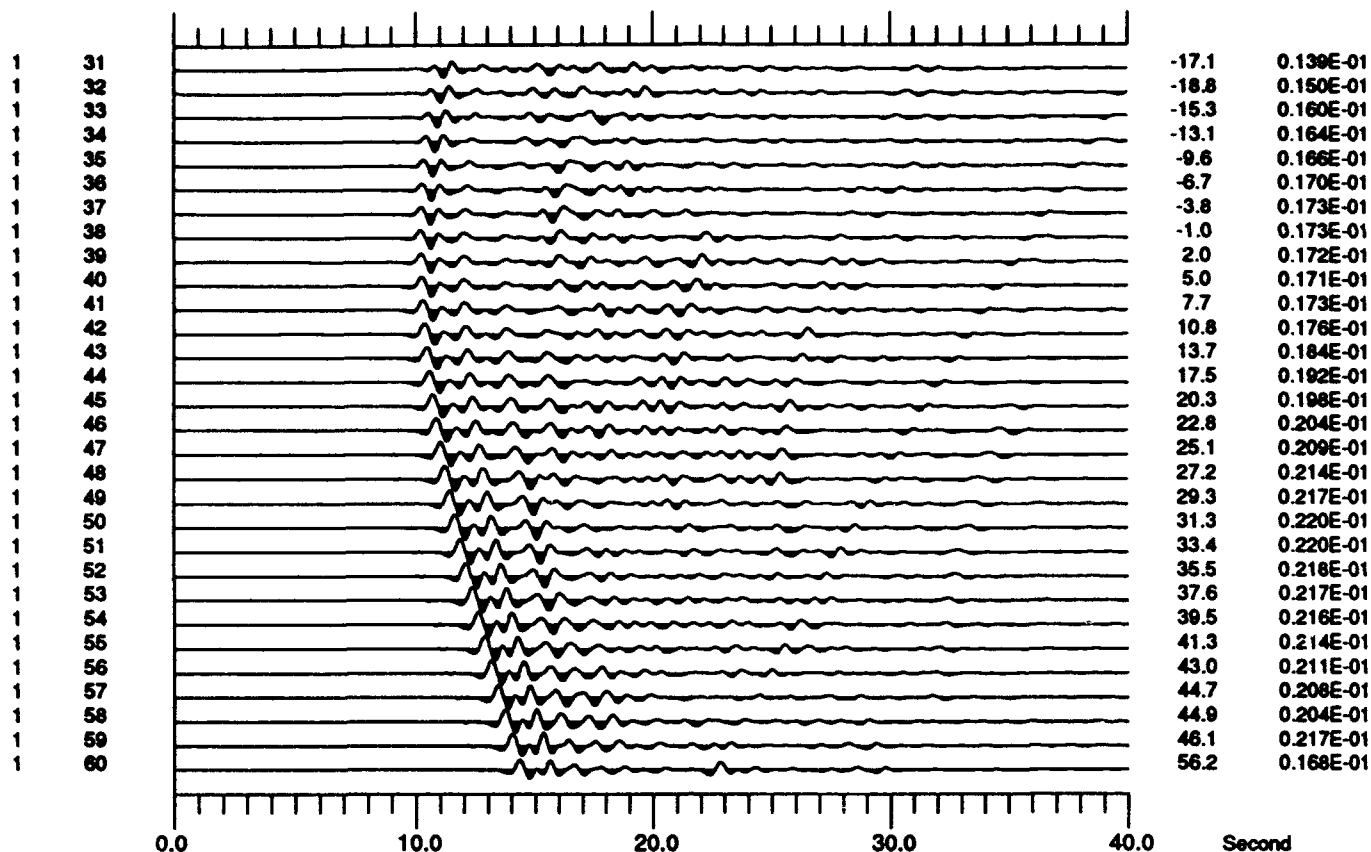
vert, same scale, decimated by 5



S, Model 65(seed 55499, Pr(1)=0.32)

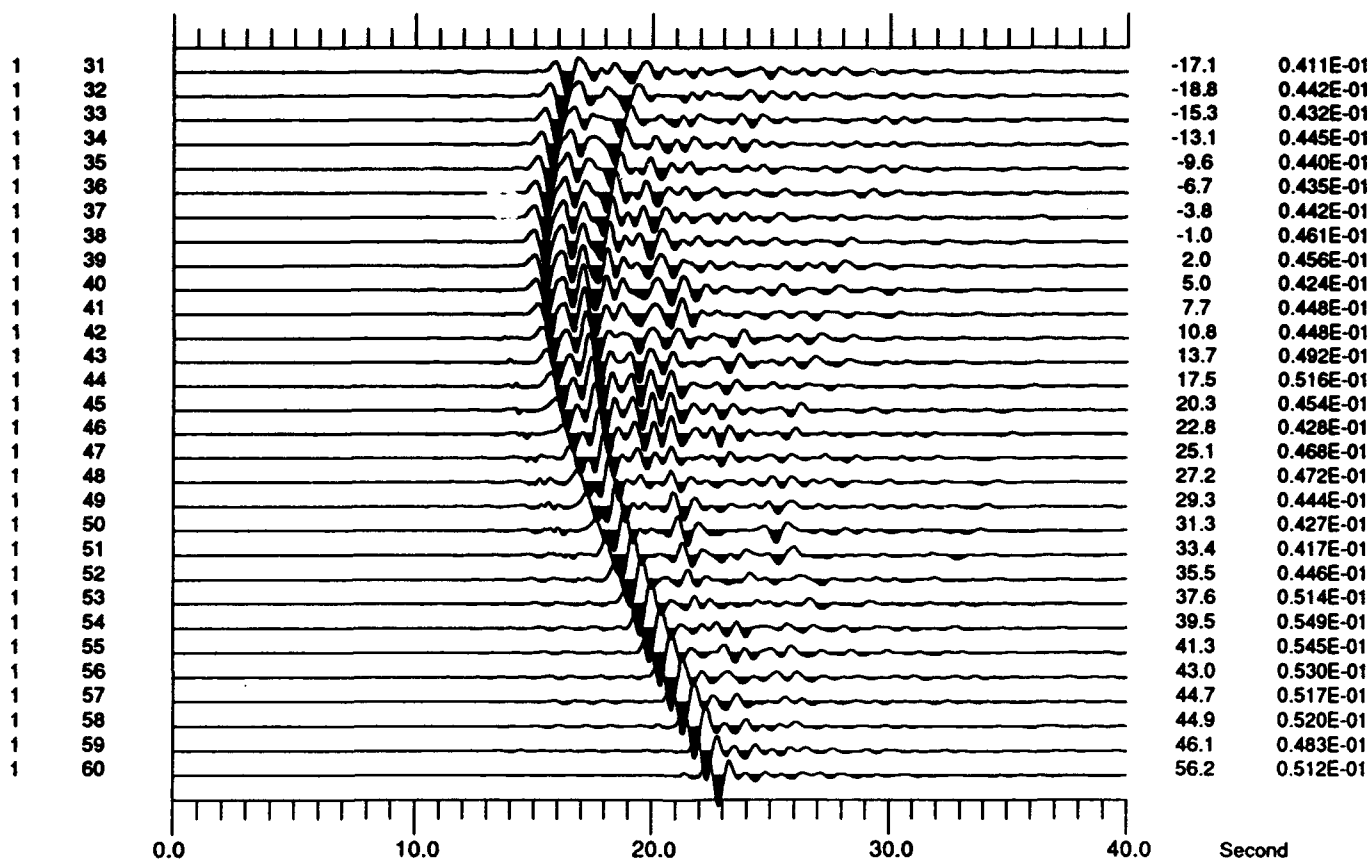
hori, same scale, decimated by 5

Figure 125



P, Model 66(seed 55446, Pr(1)=0.32)

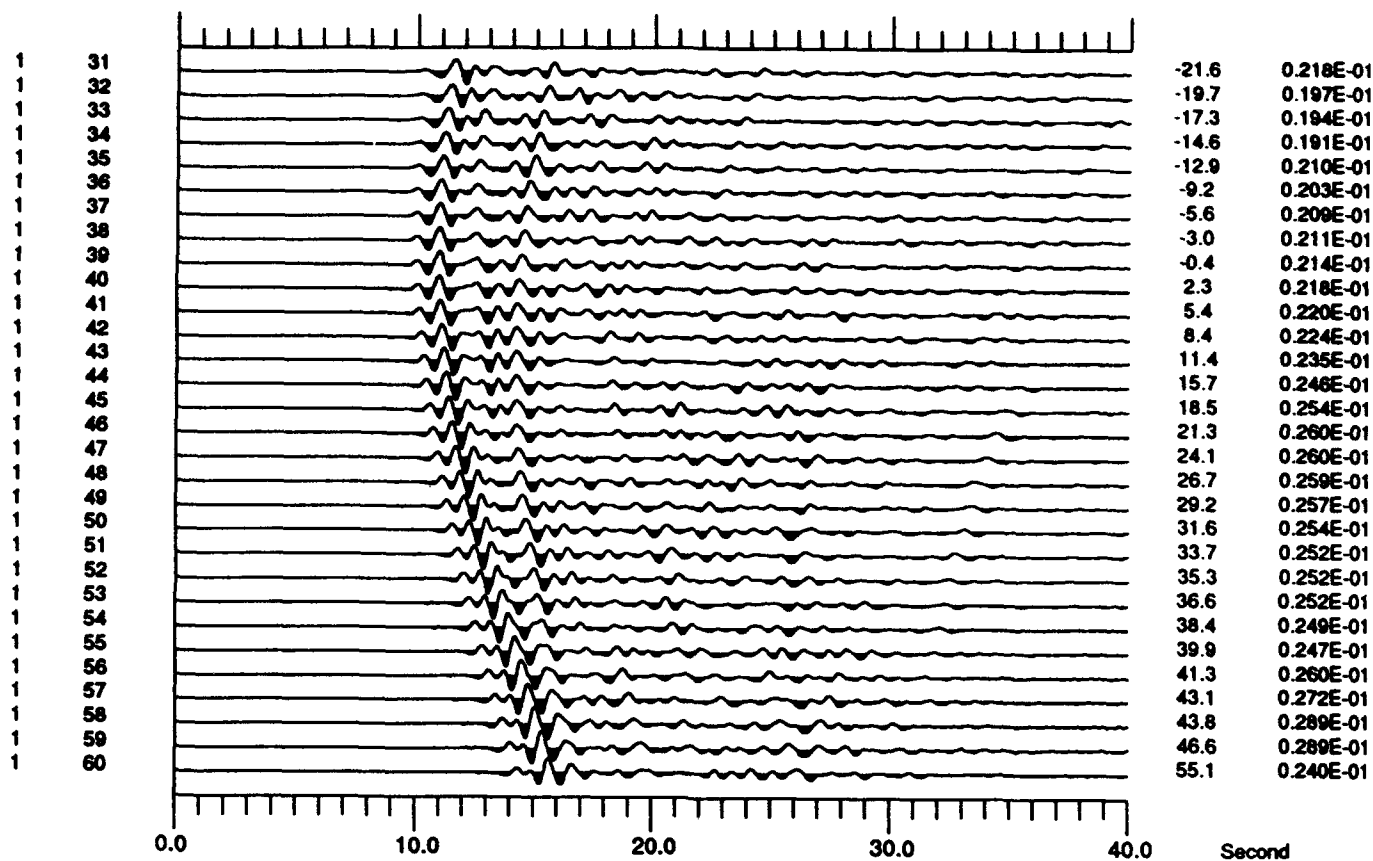
vert, same scale, decimated by 5



S, Model 66(seed 55446, Pr(1)=0.32)

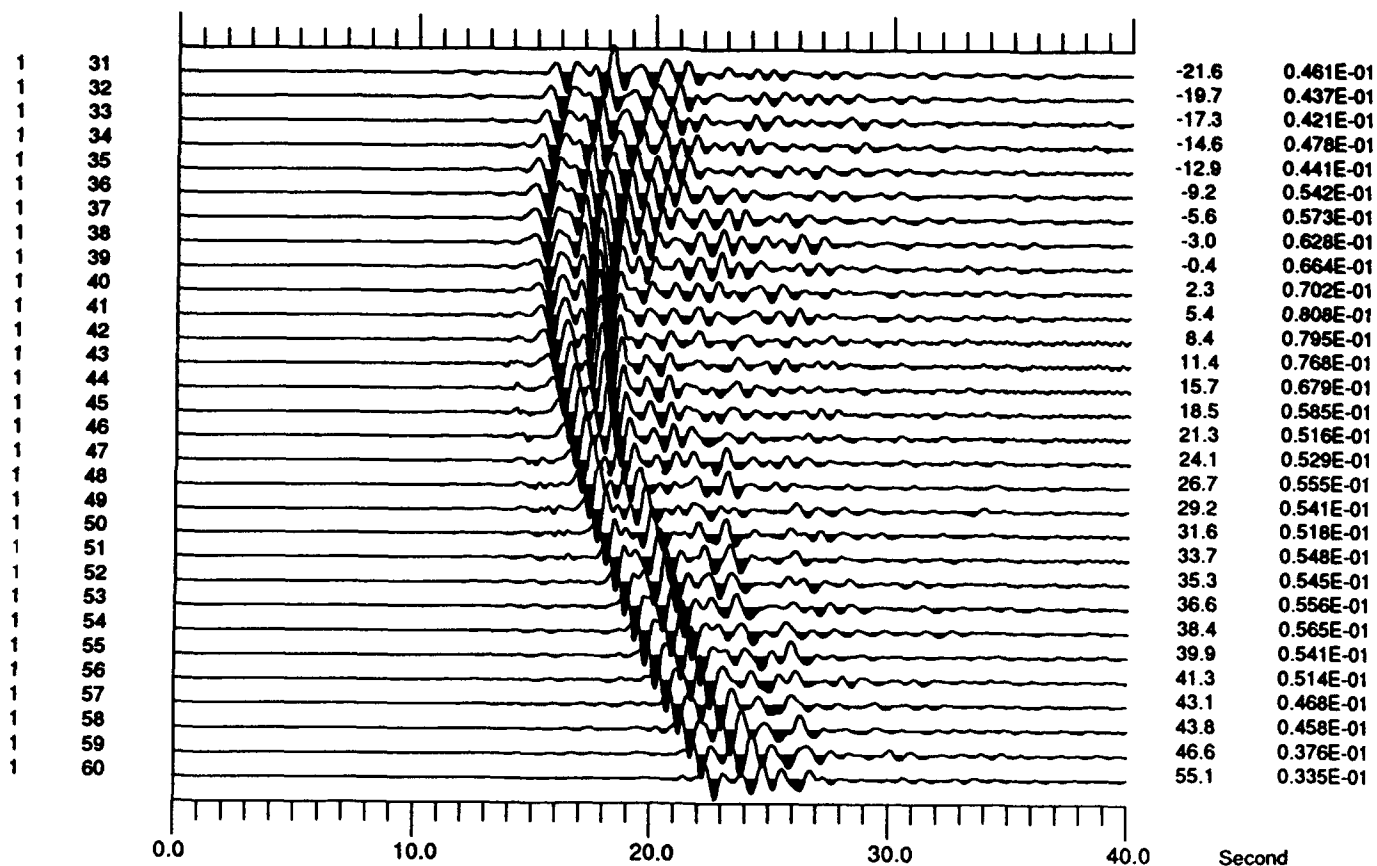
hori, same scale, decimated by 5

Figure 126



P, Model 71(seed 22192, Pr(1)=0.35)

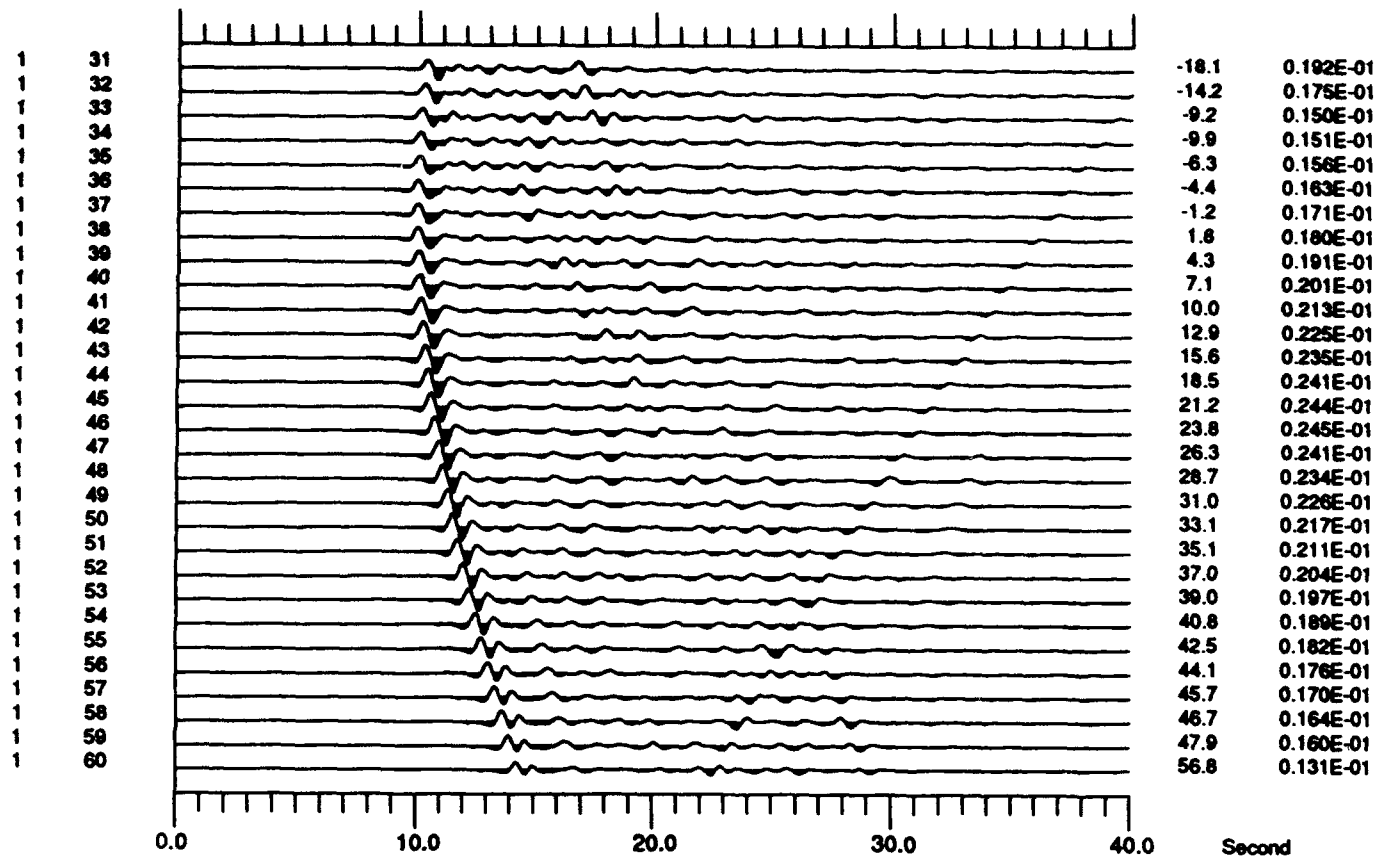
vert, same scale, decimated by 5



S, Model 71(seed 22192, Pr(1)=0.35)

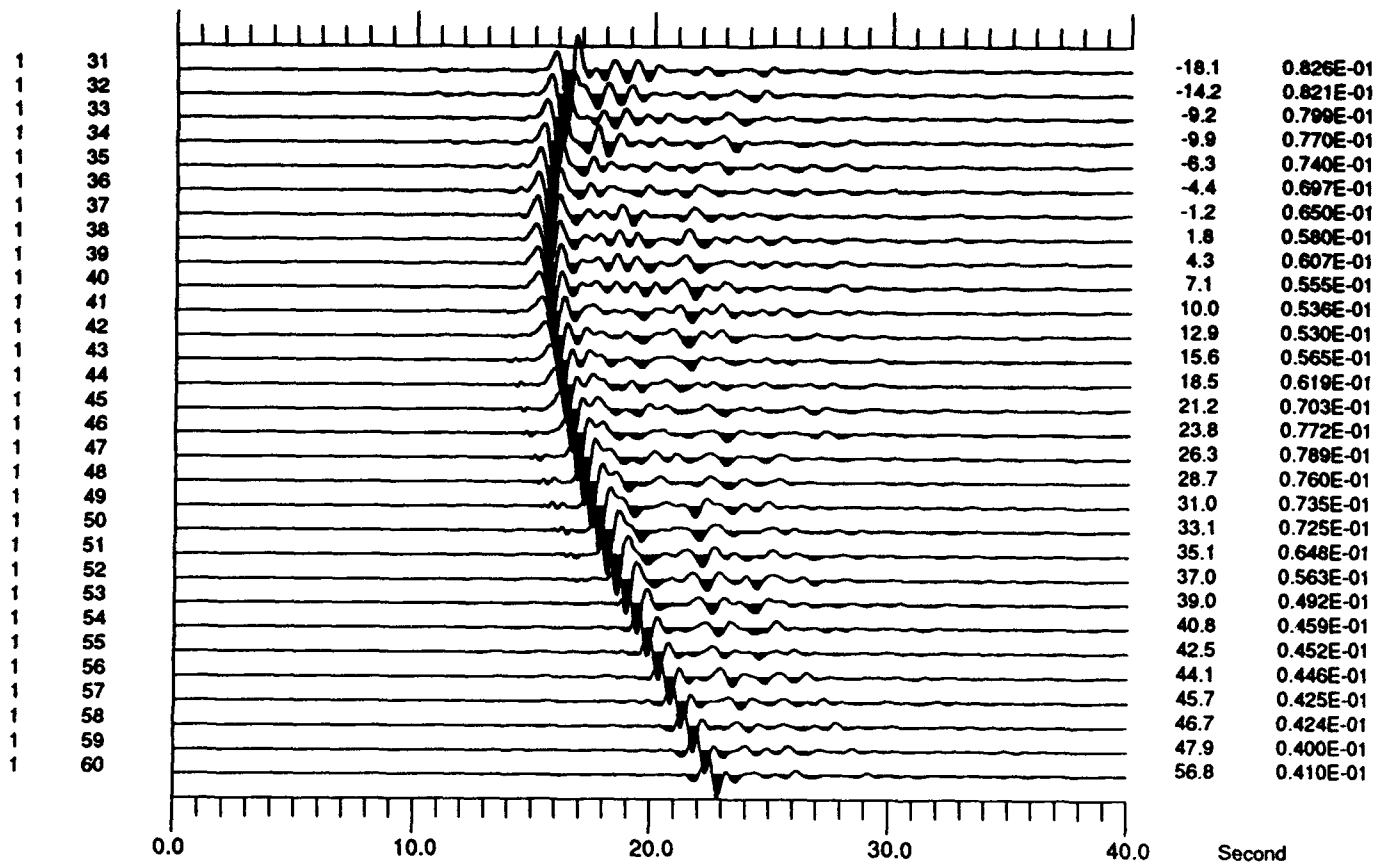
hori, same scale, decimated by 5

Figure 127



P, Model 72(seed 31087, Pr(1)=0.35)

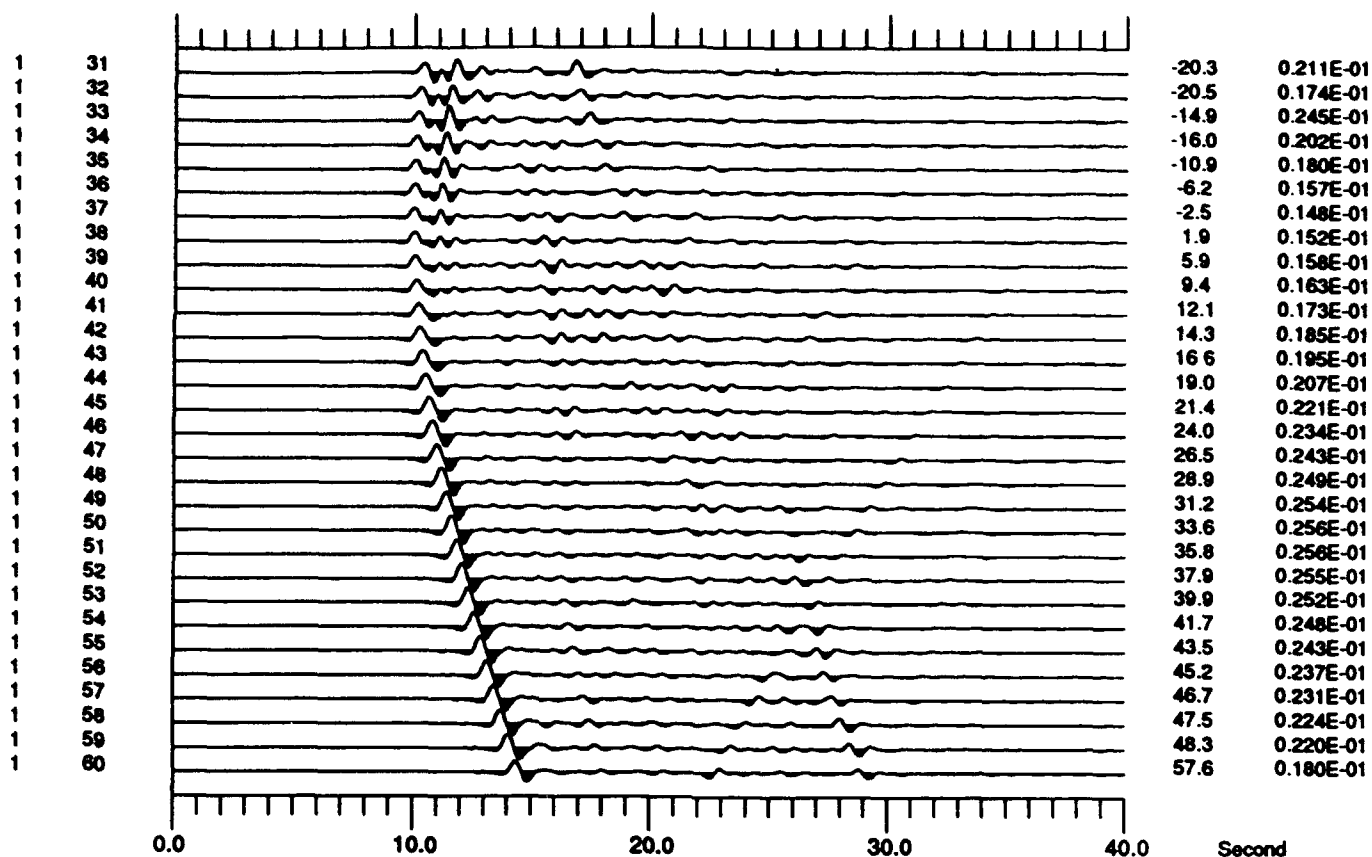
vert, same scale, decimated by 5



S, Model 72(seed 31087, Pr(1)=0.35)

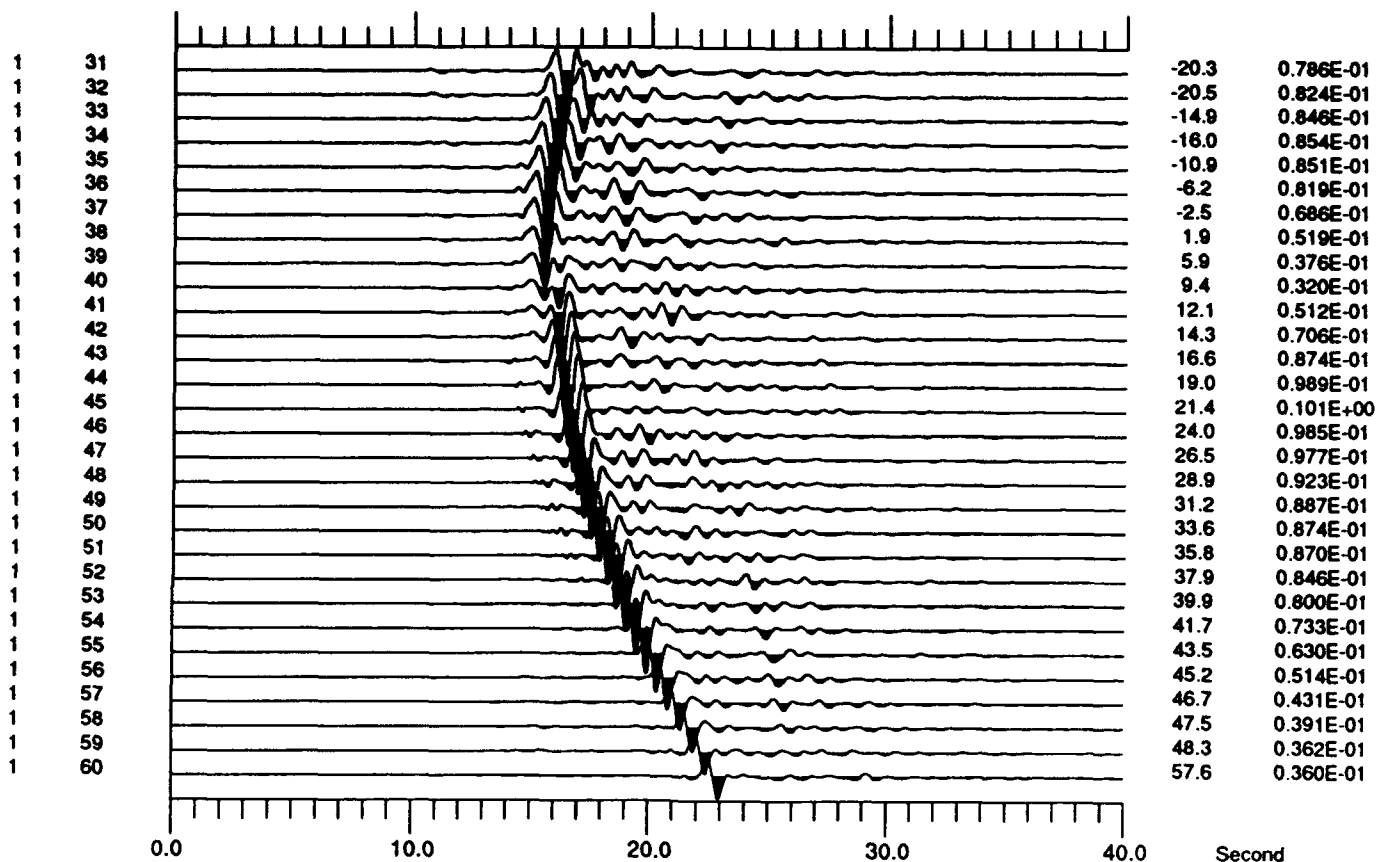
hori, same scale, decimated by 5

Figure 128



P, Model 73(seed 86061, Pr(1)=0.35)

vert, same scale, decimated by 5



S, Model 73(seed 86061, Pr(1)=0.35)

hori, same scale, decimated by 5

Figure 129

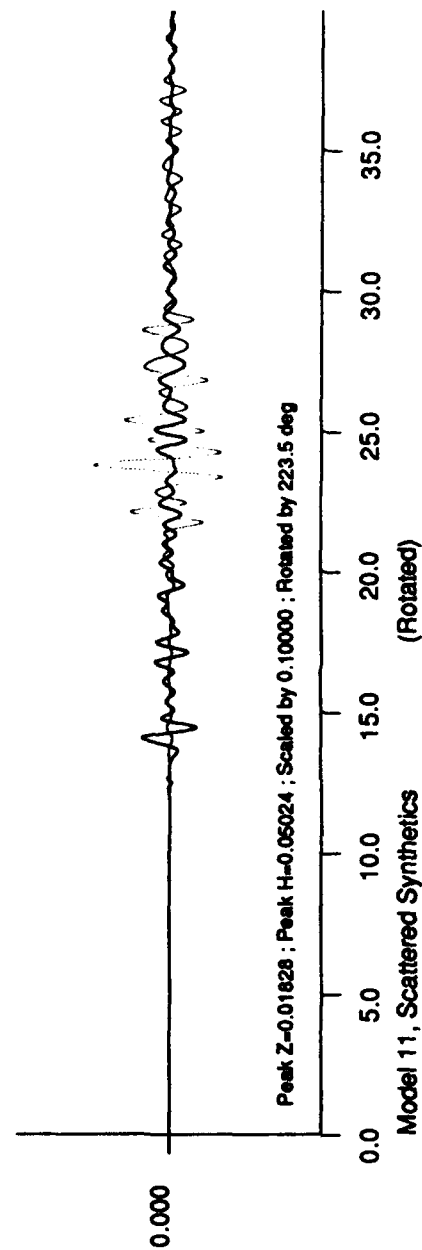
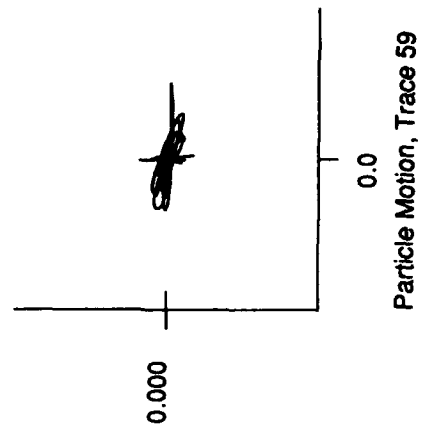
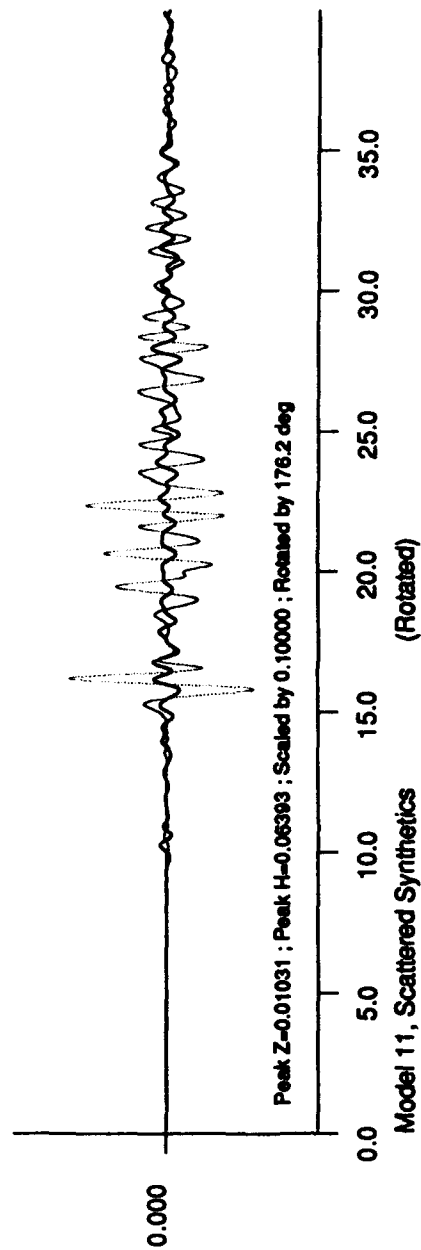
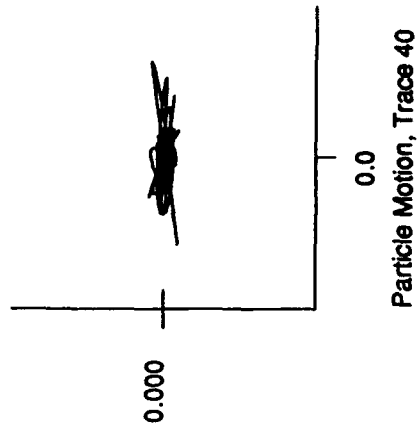
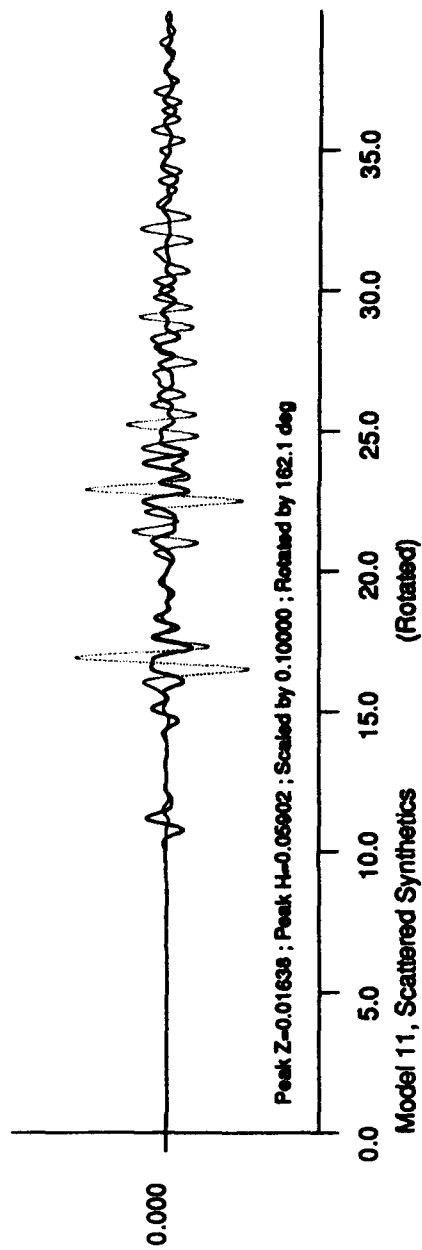
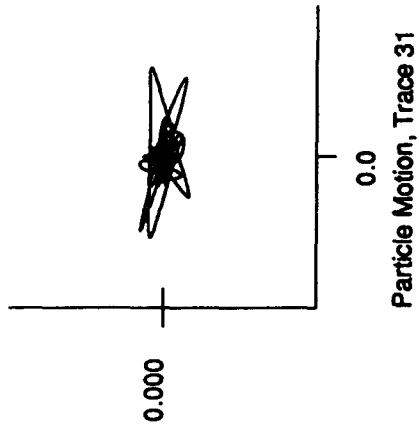


Figure 130

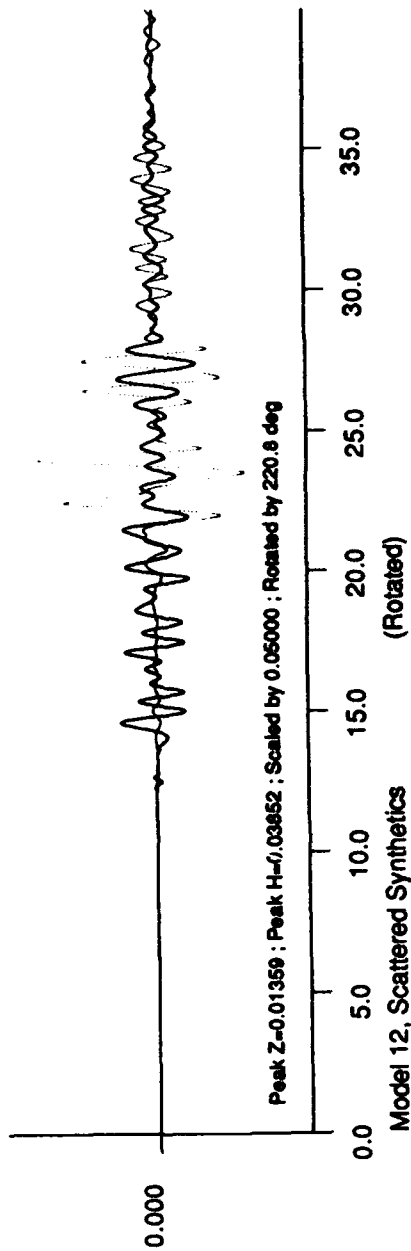
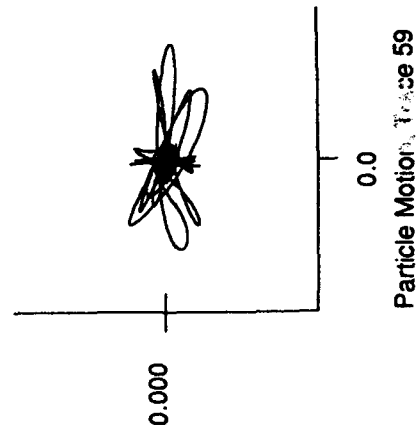
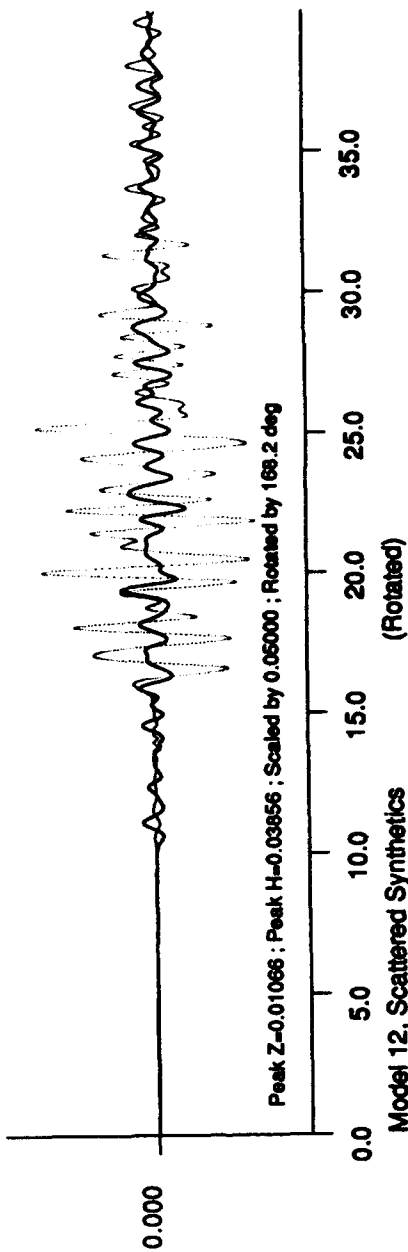
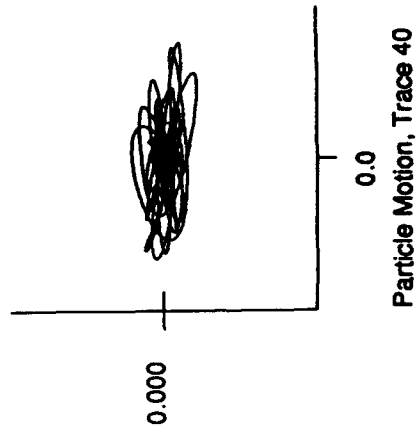
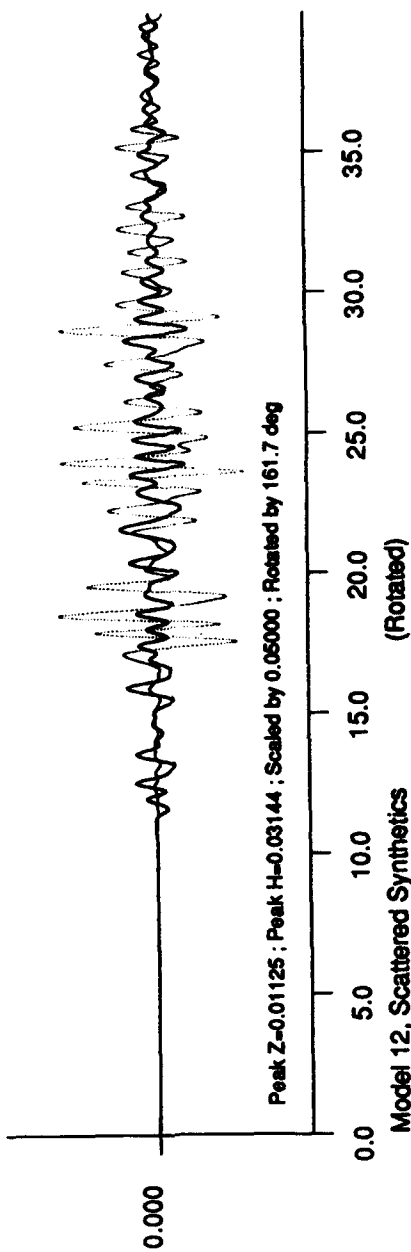
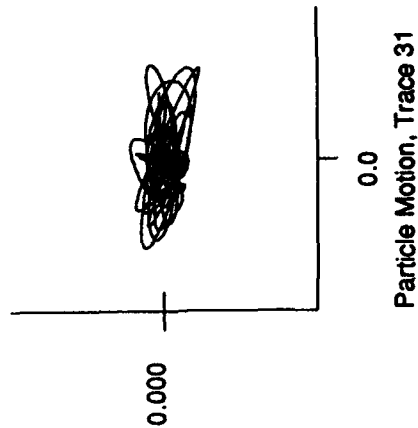


Figure 131

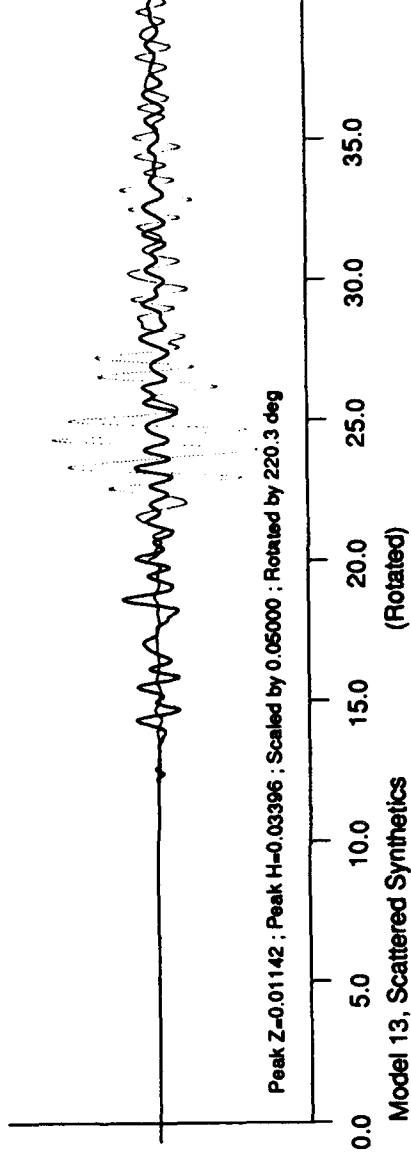
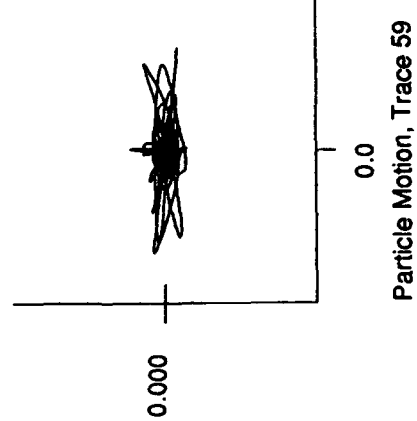
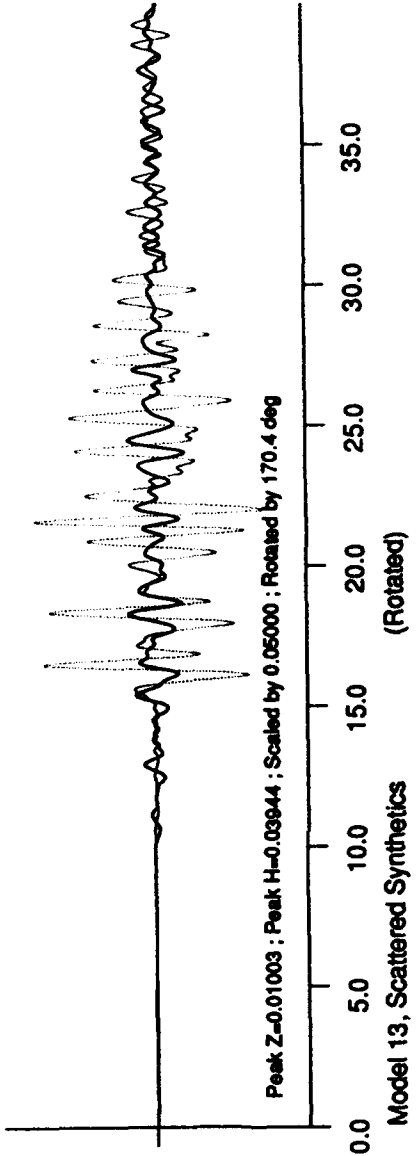
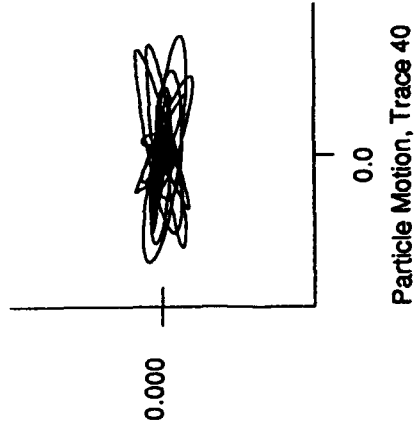
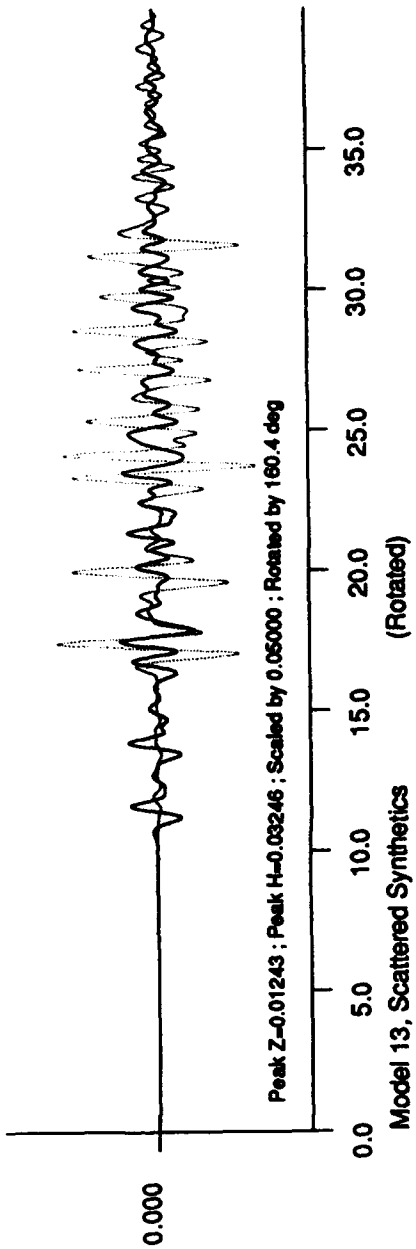
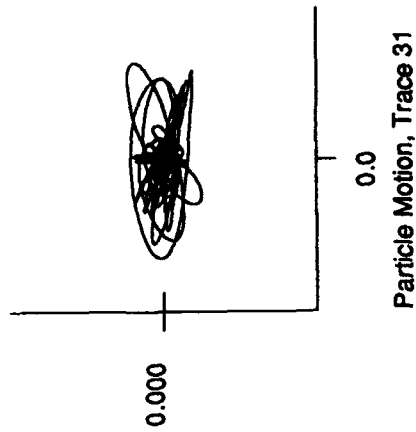


Figure 132

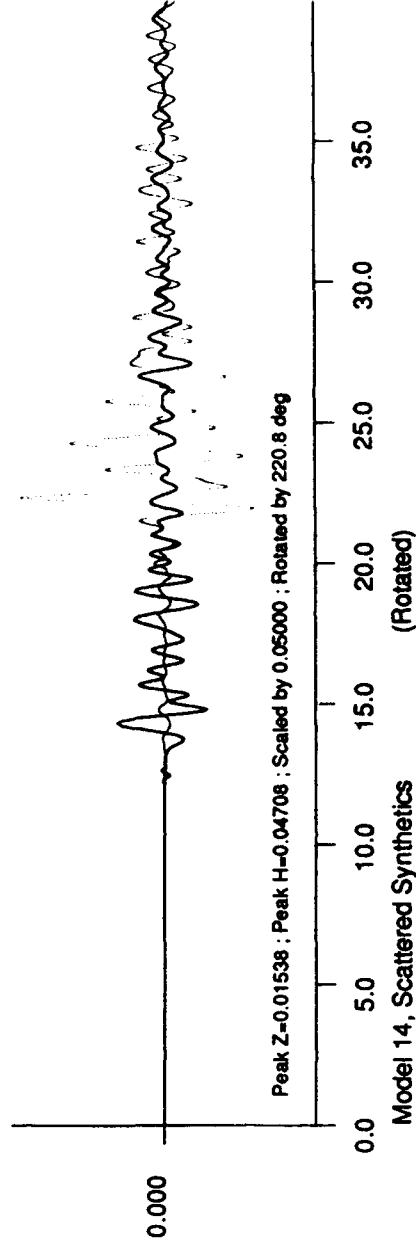
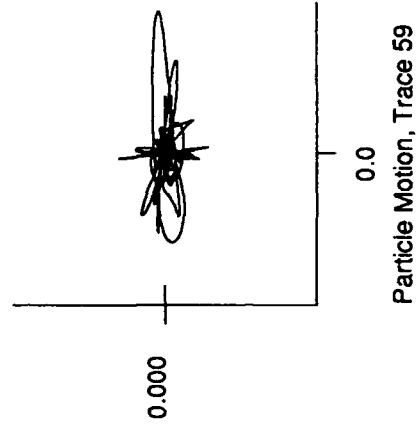
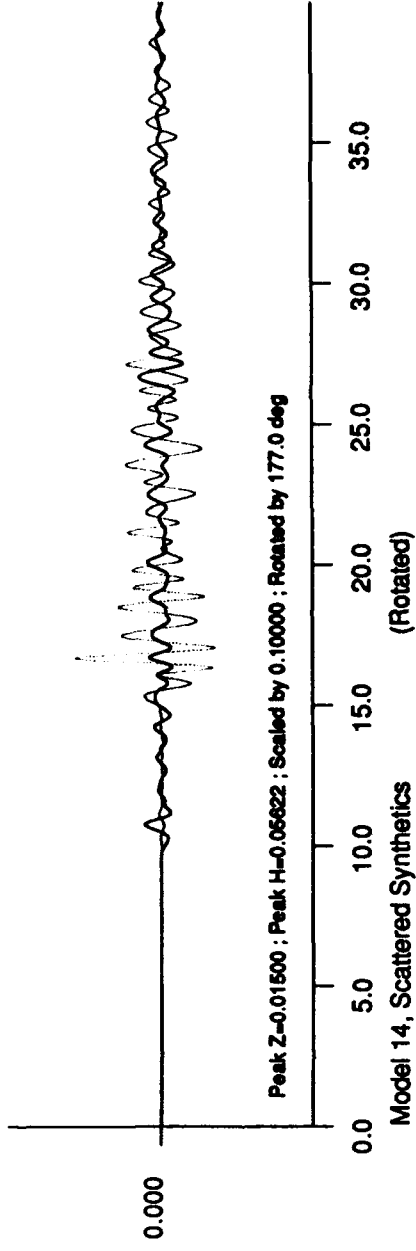
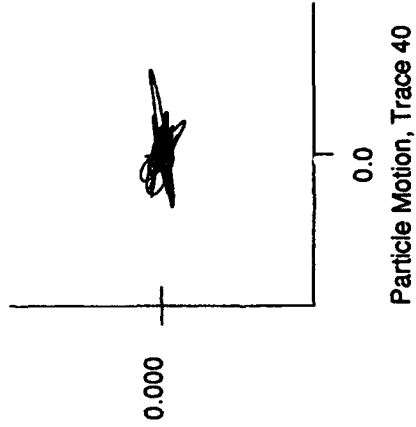
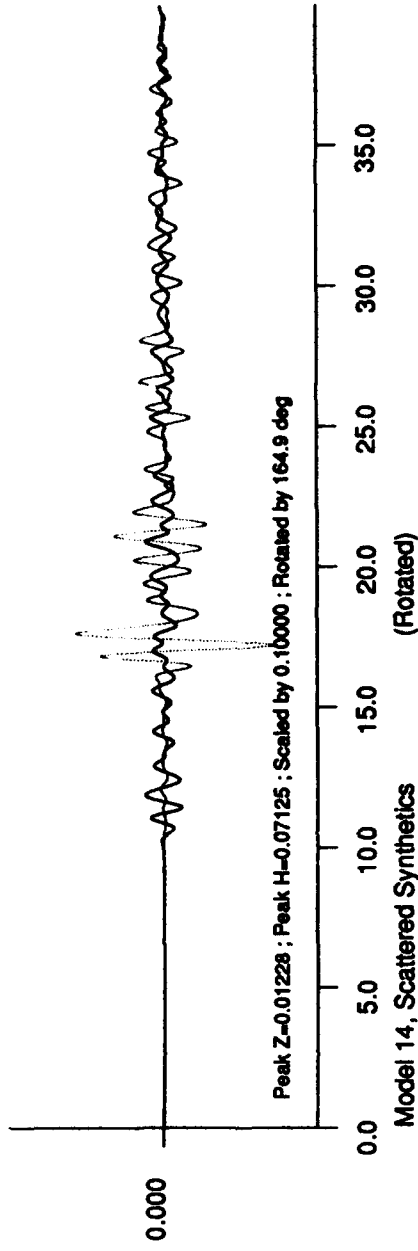
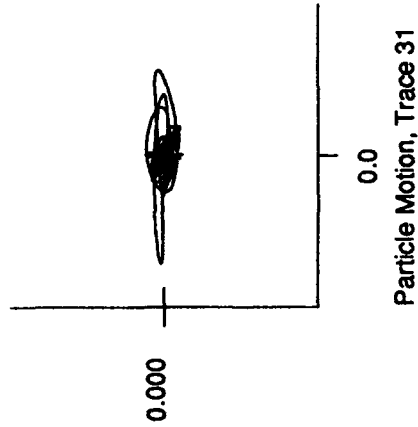


Figure 133

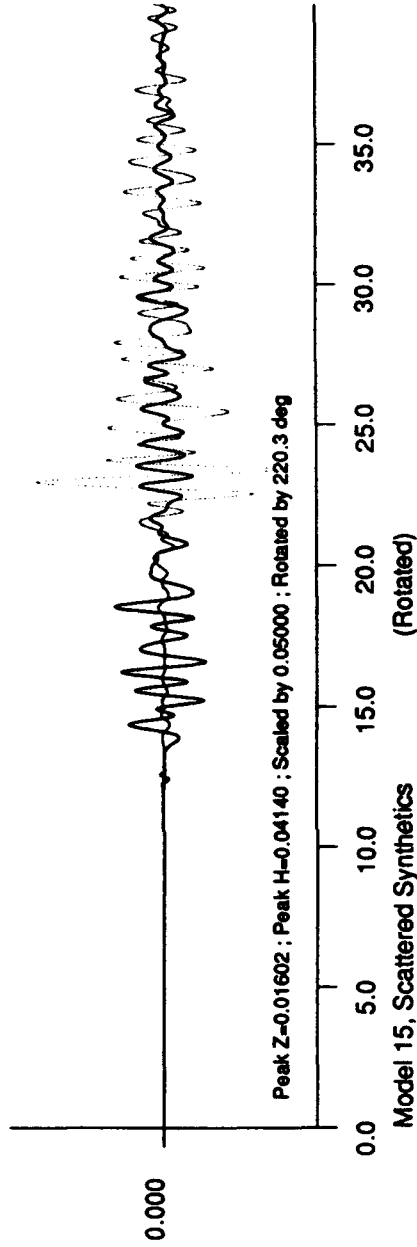
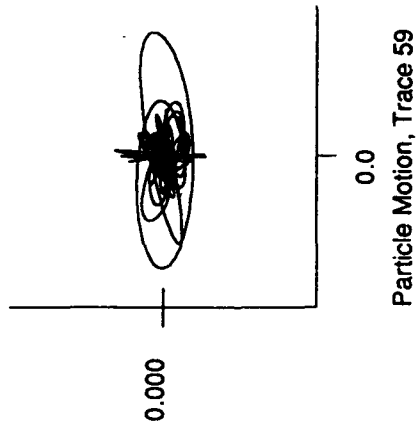
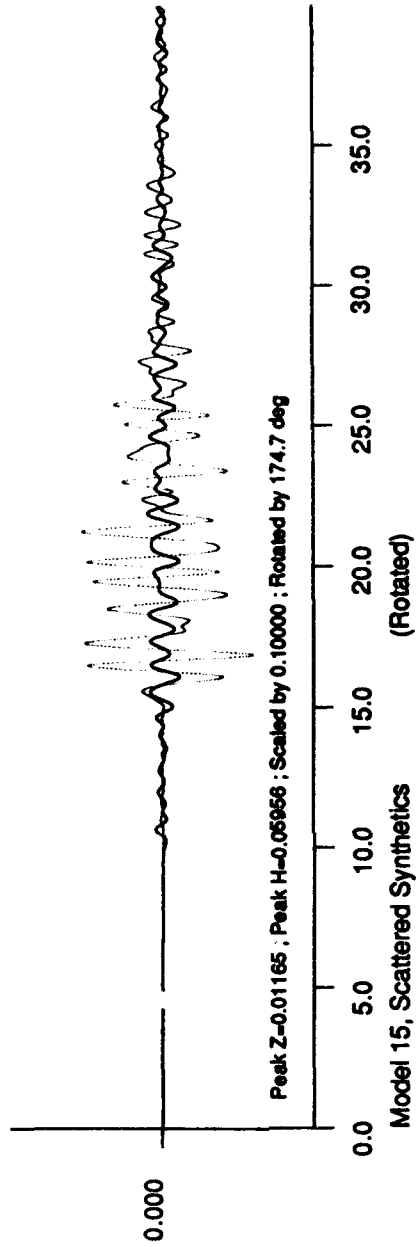
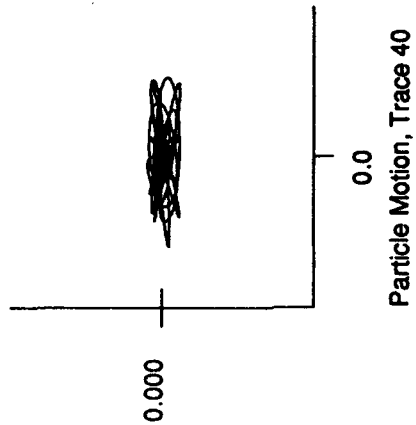
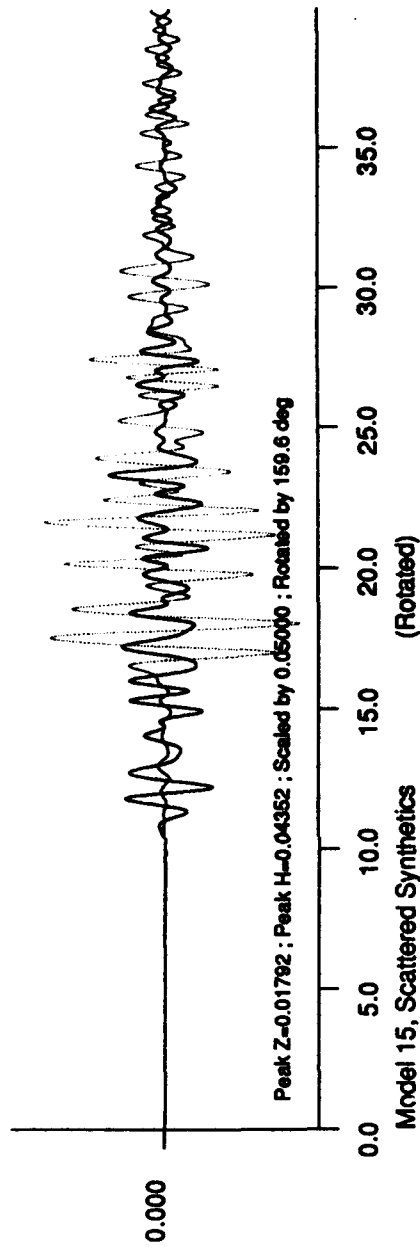
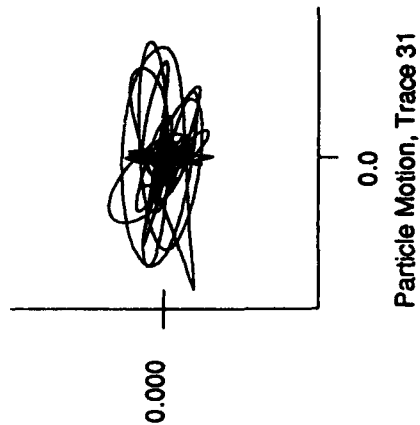


Figure 134

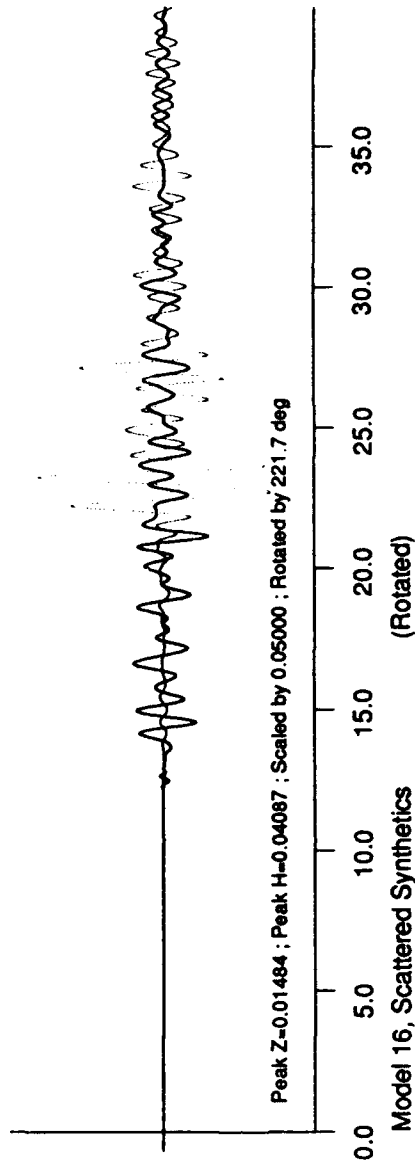
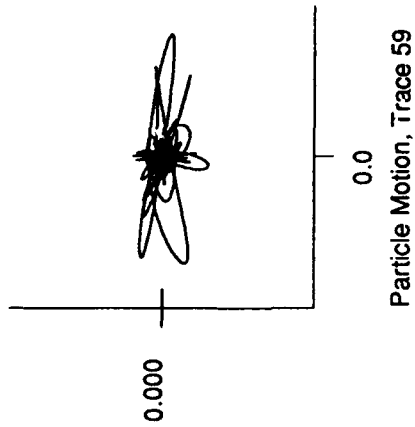
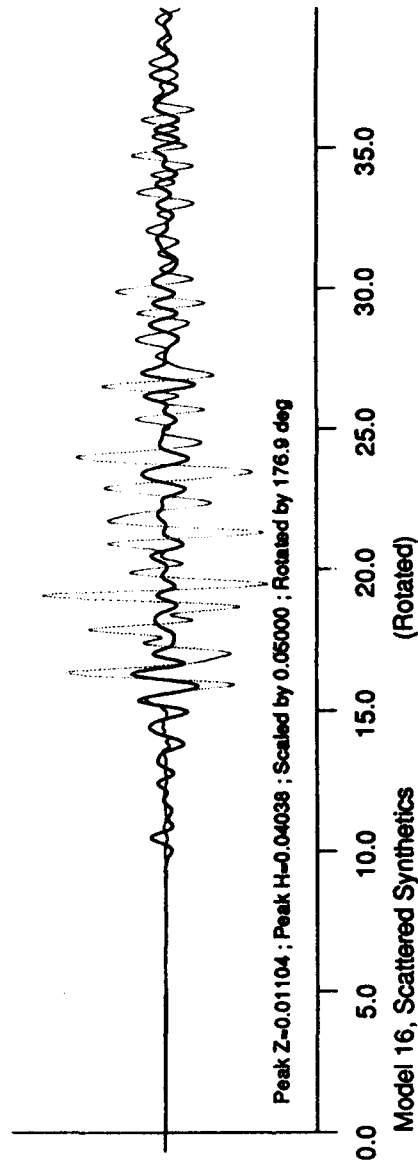
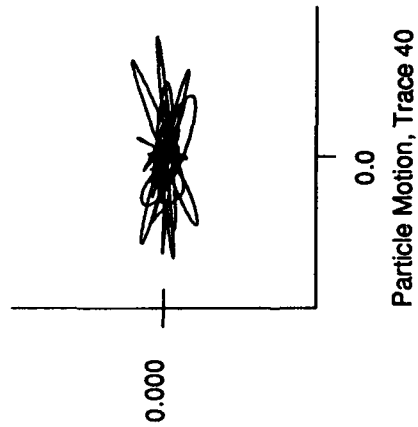
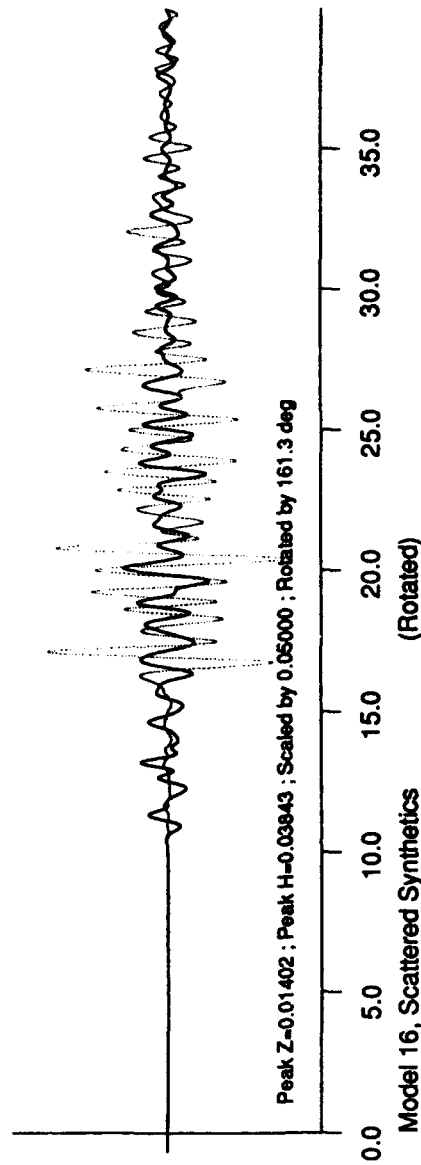
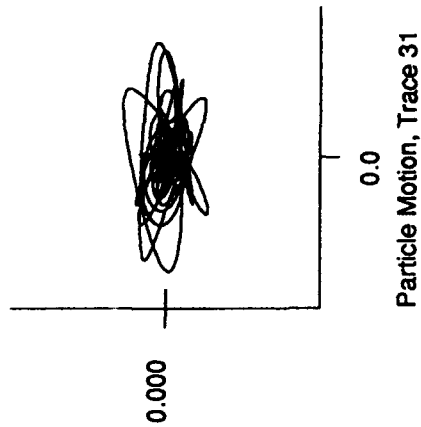


Figure 135

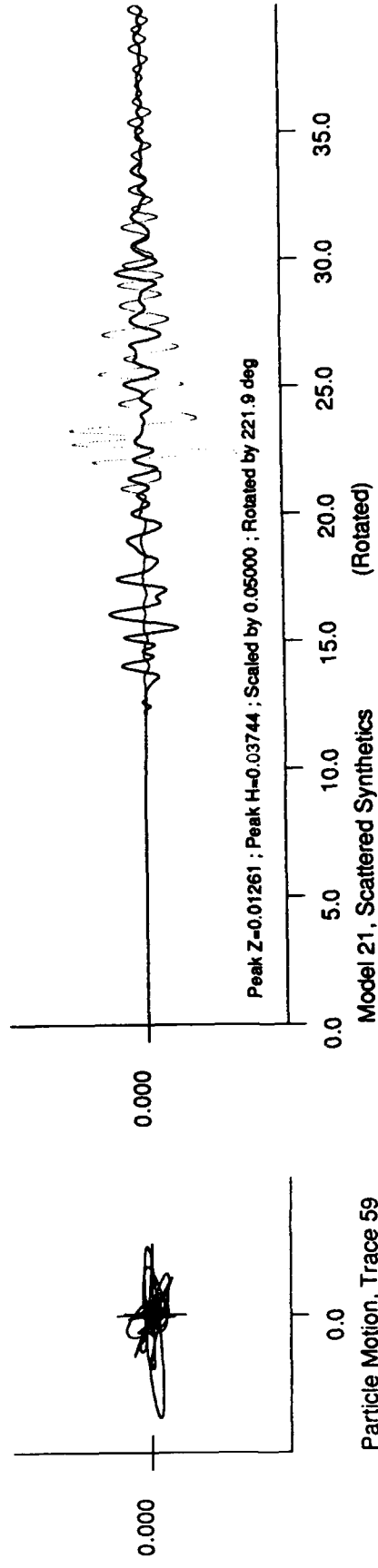
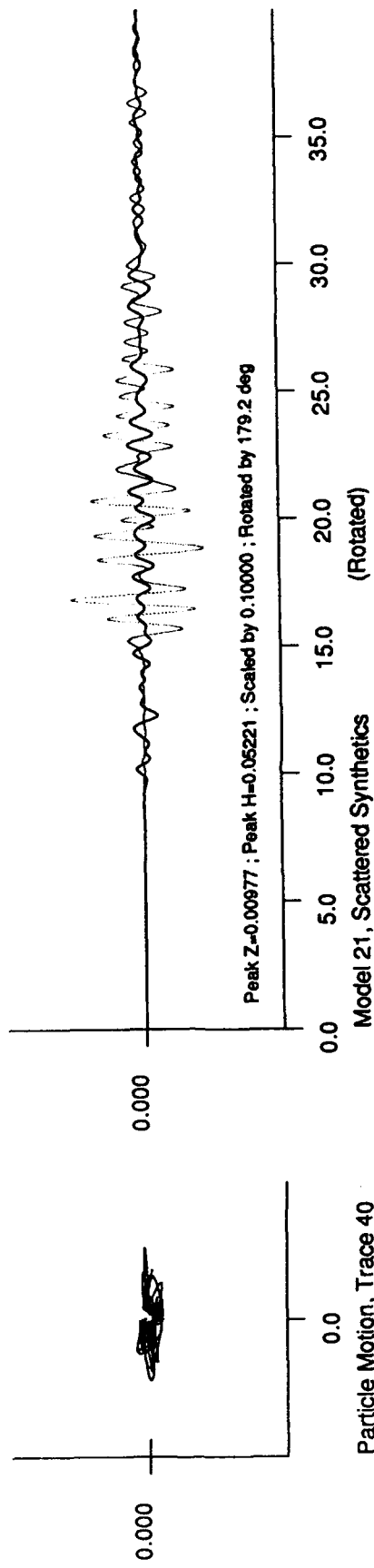
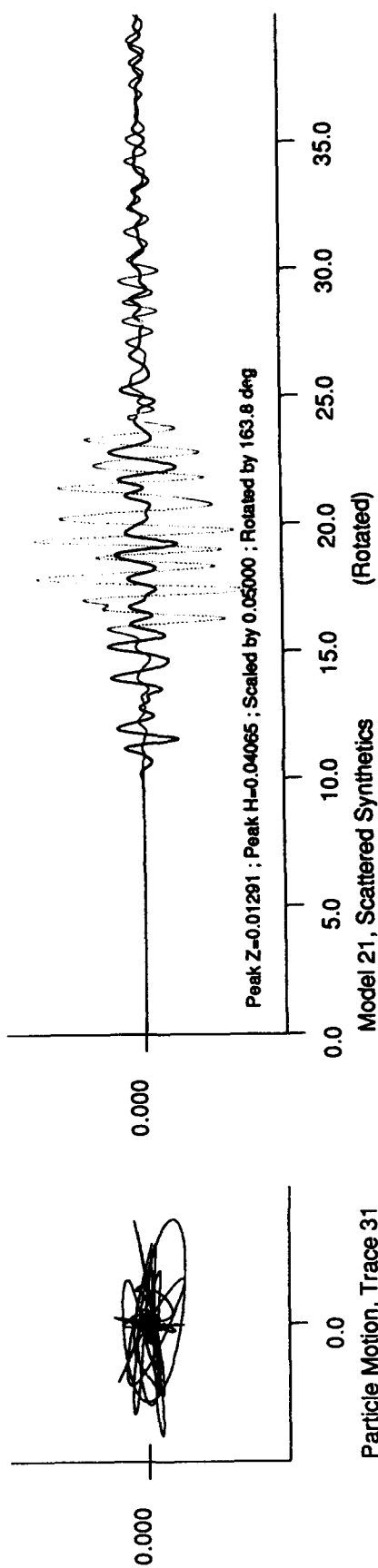


Figure 136

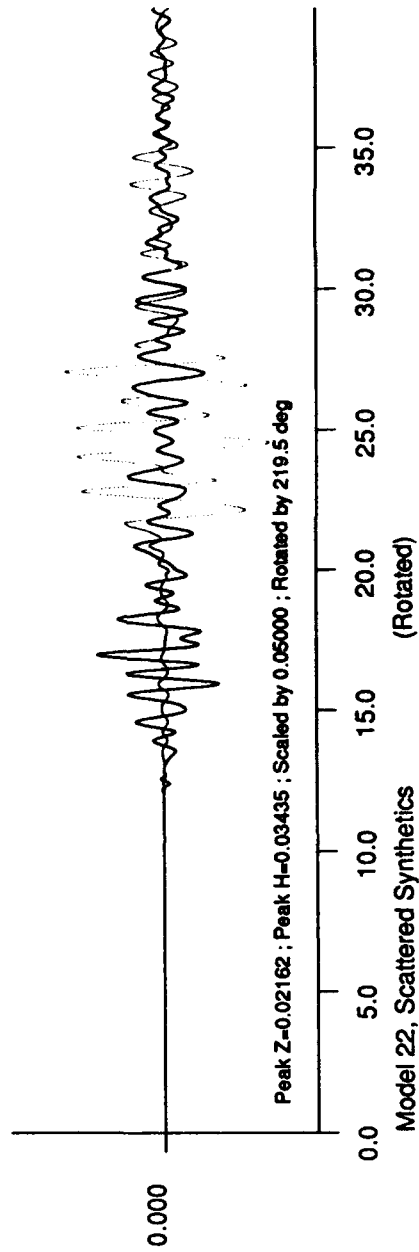
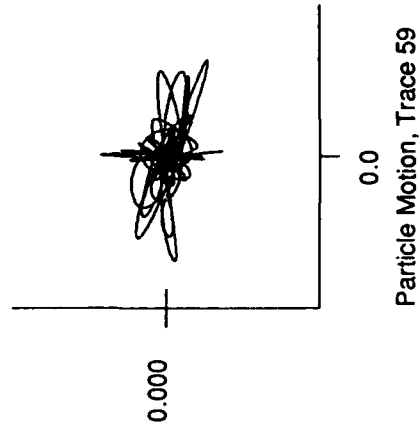
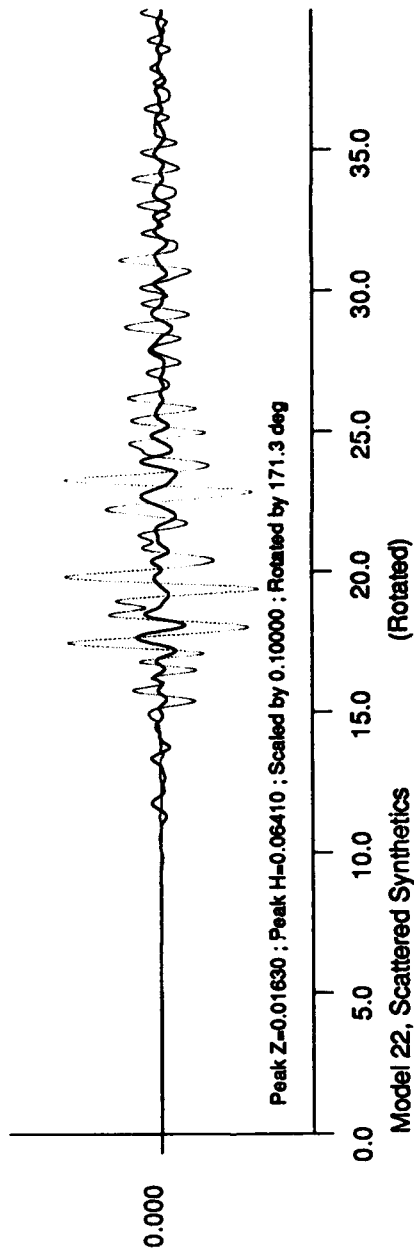
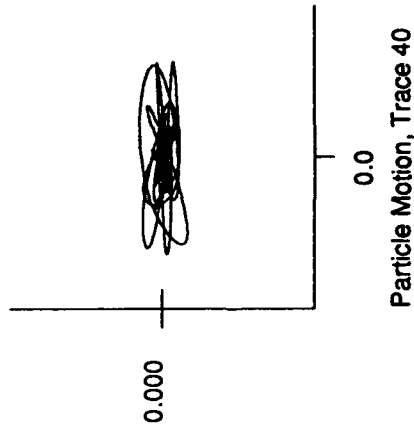
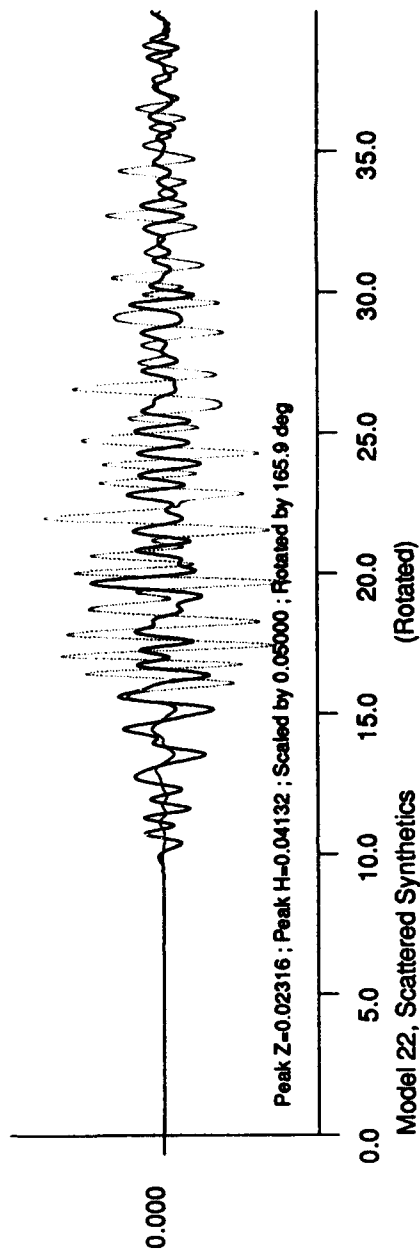
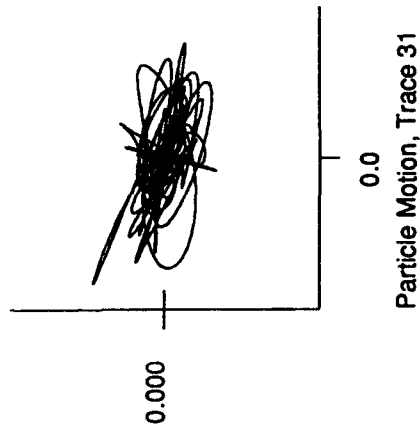


Figure 137

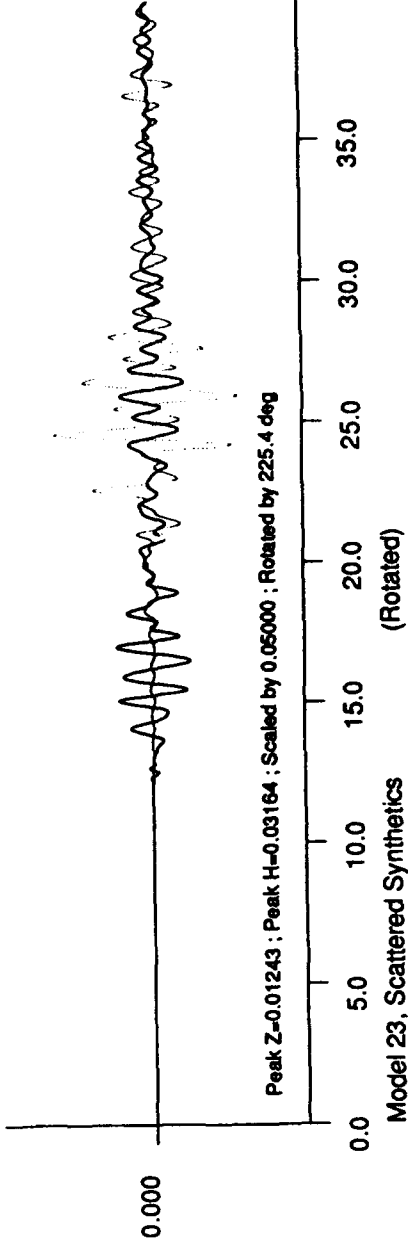
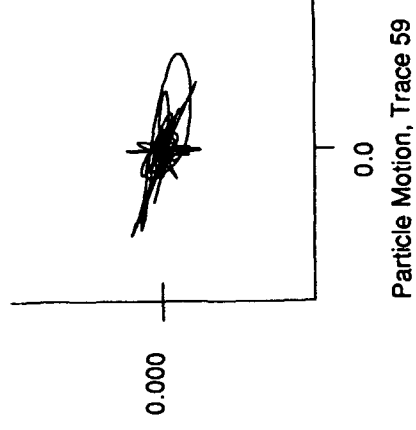
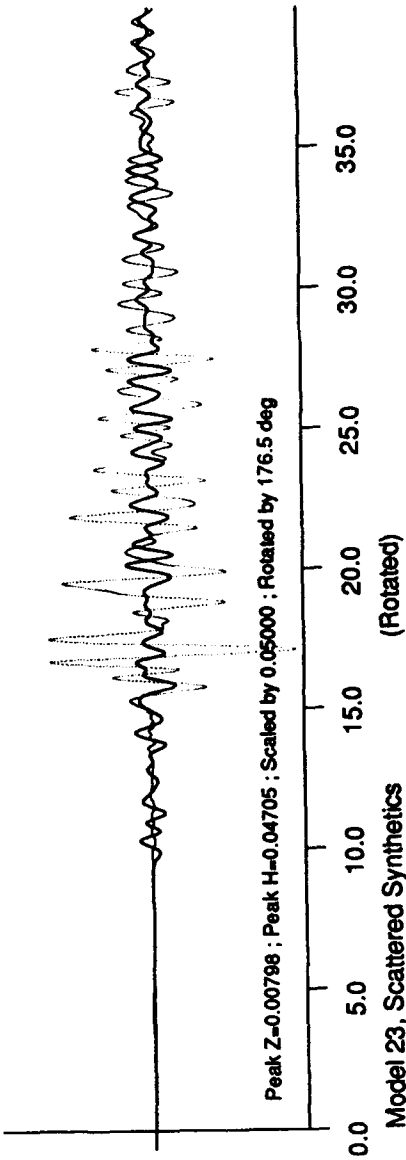
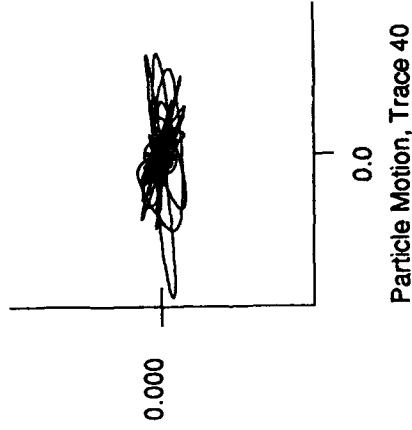
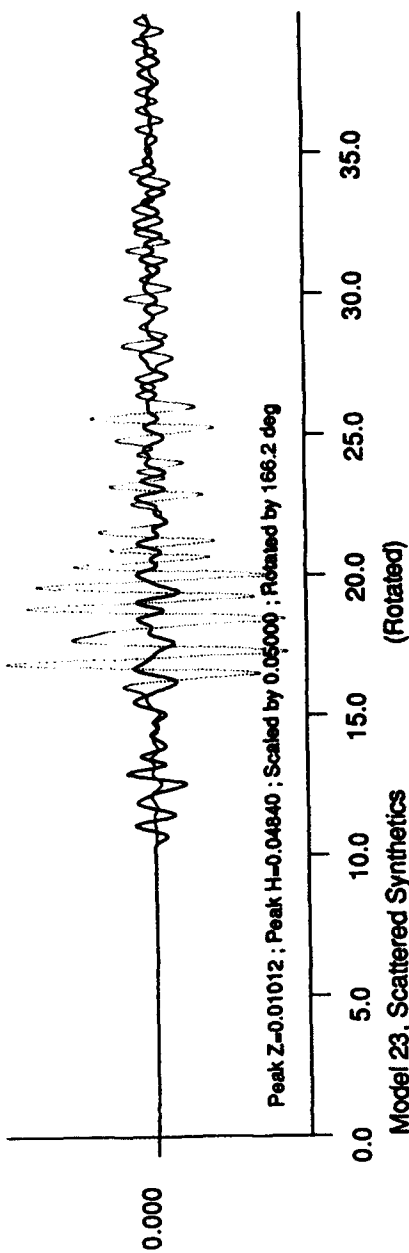
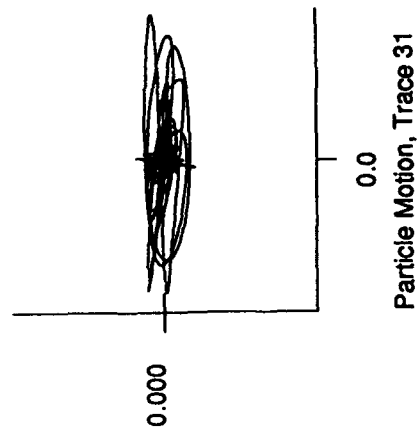


Figure 138

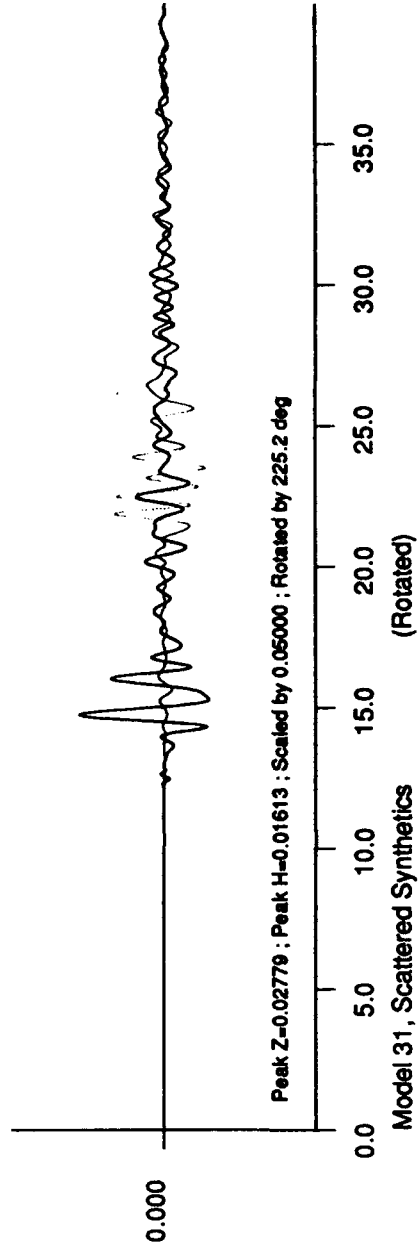
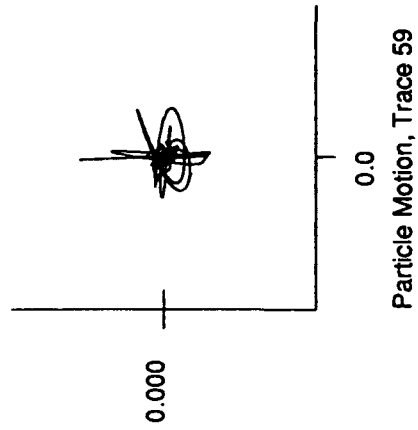
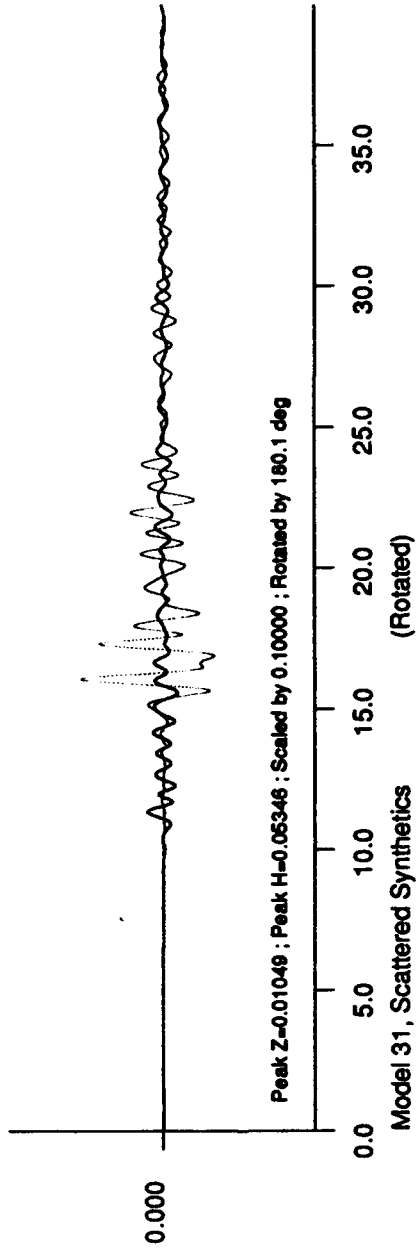
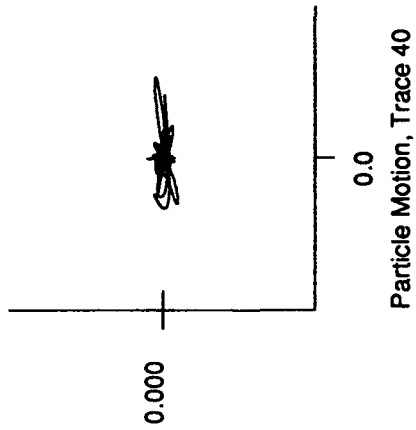
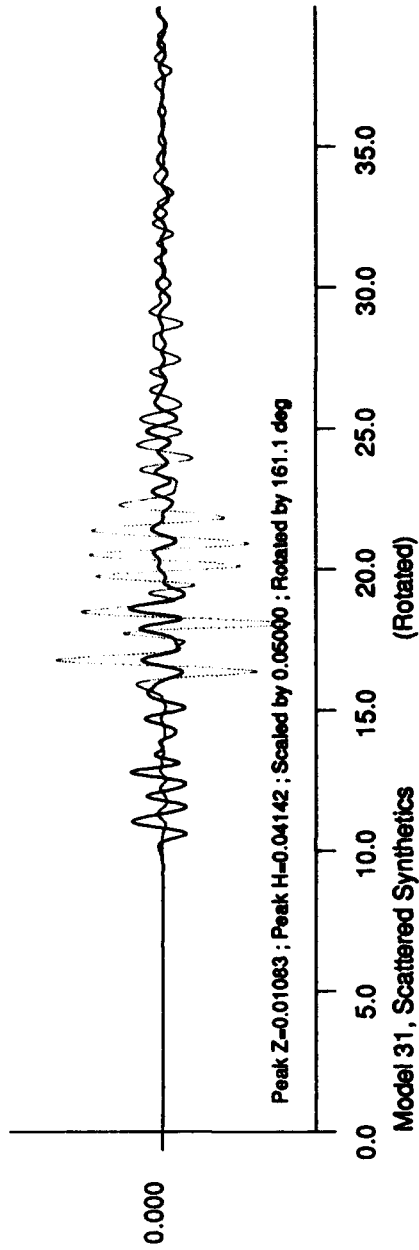
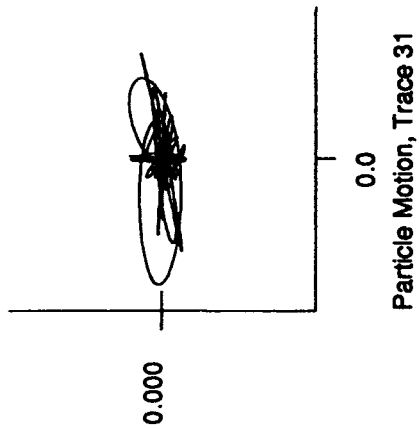
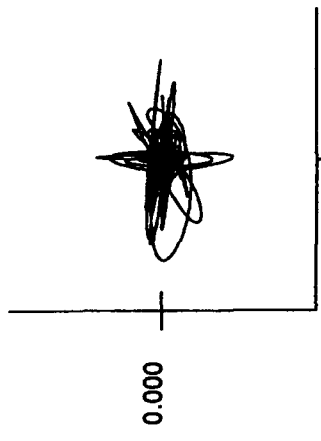
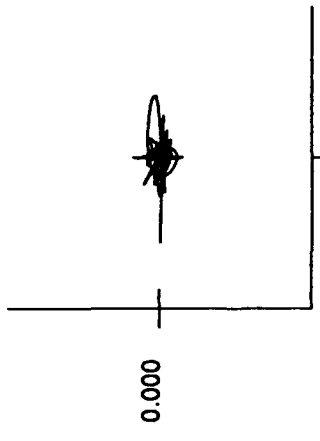
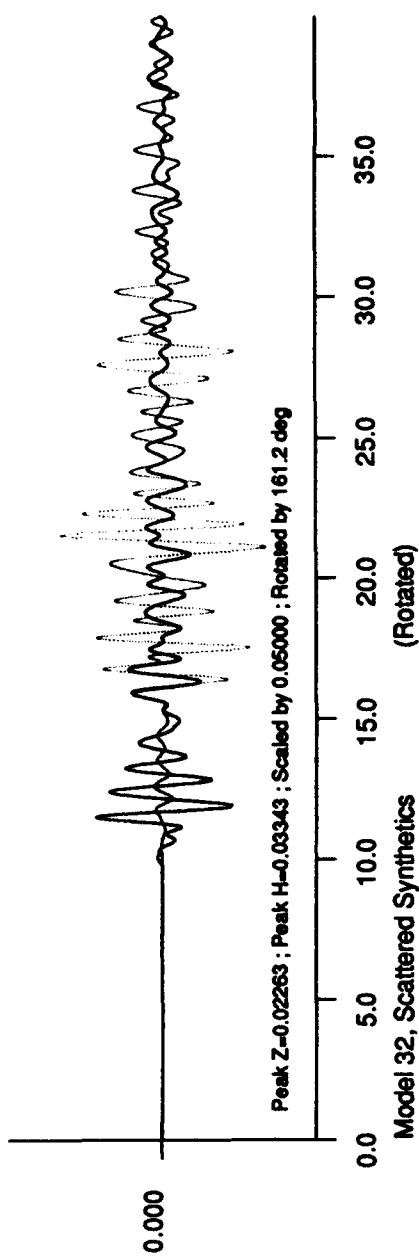


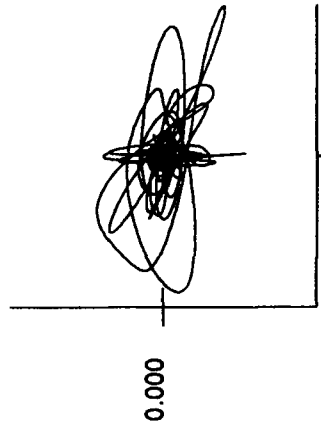
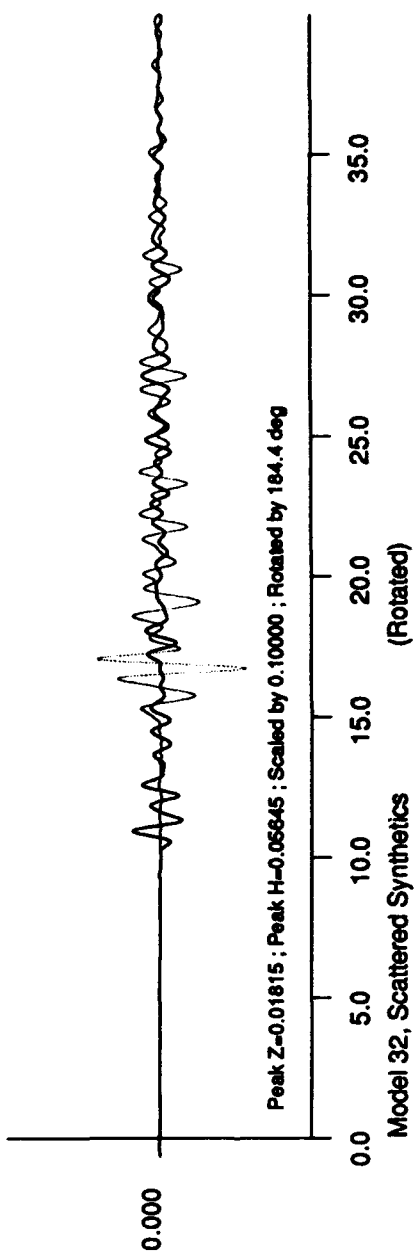
Figure 139



Particle Motion, Trace 31



Particle Motion, Trace 40



Particle Motion, Trace 59

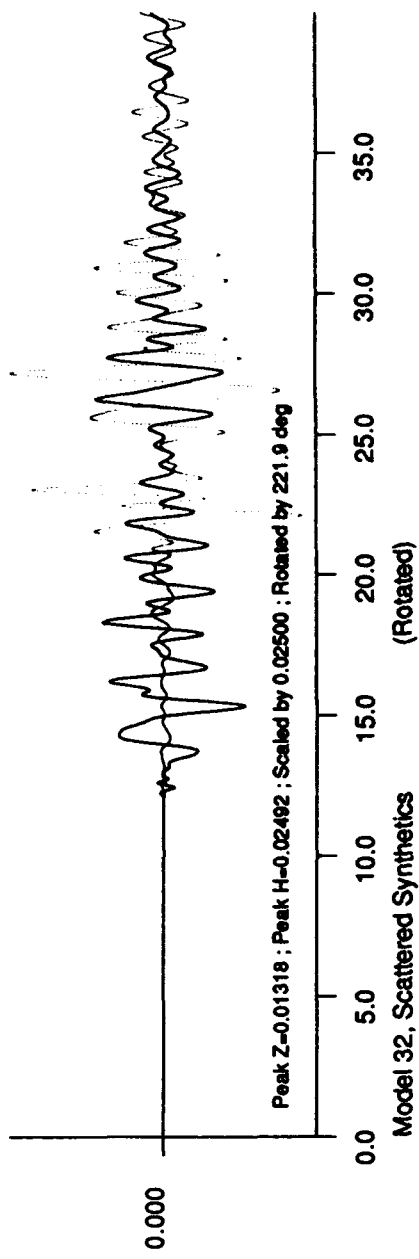


Figure 140

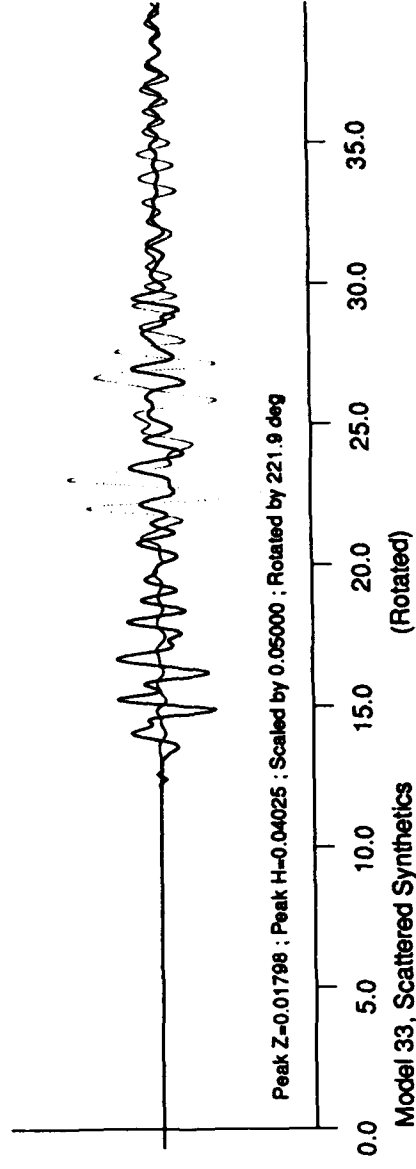
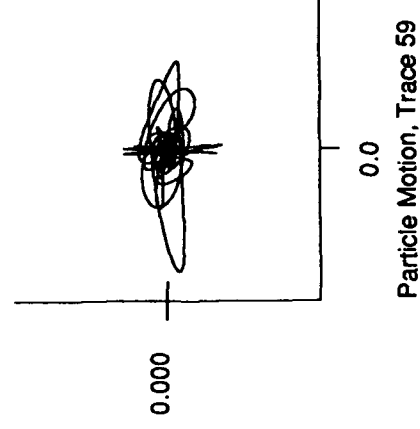
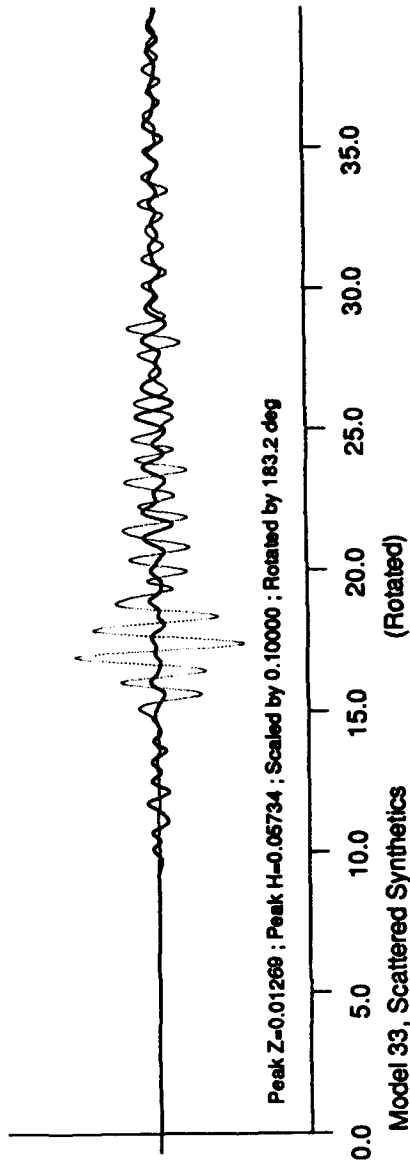
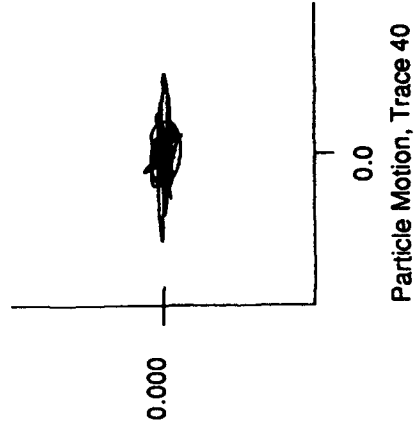
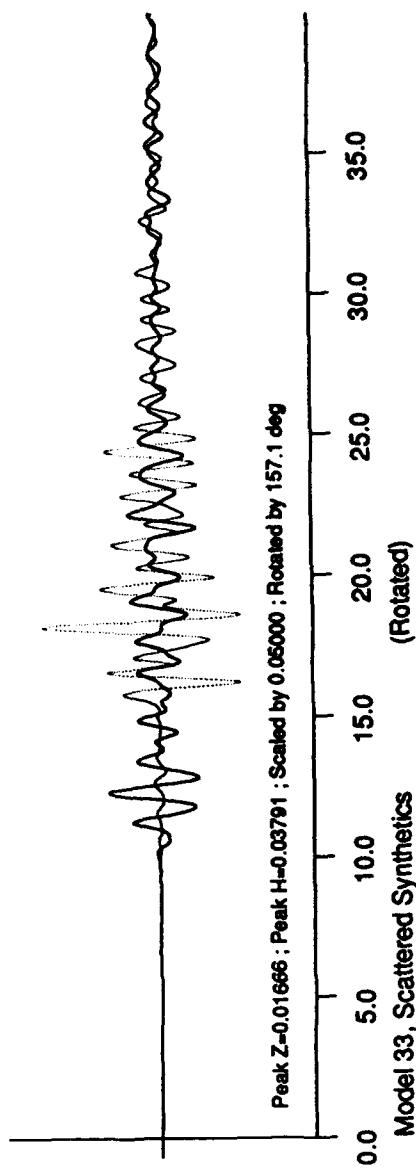
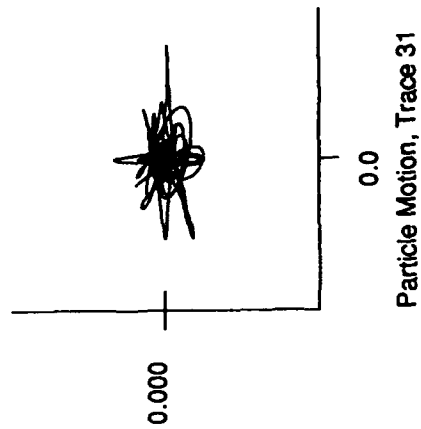


Figure 141

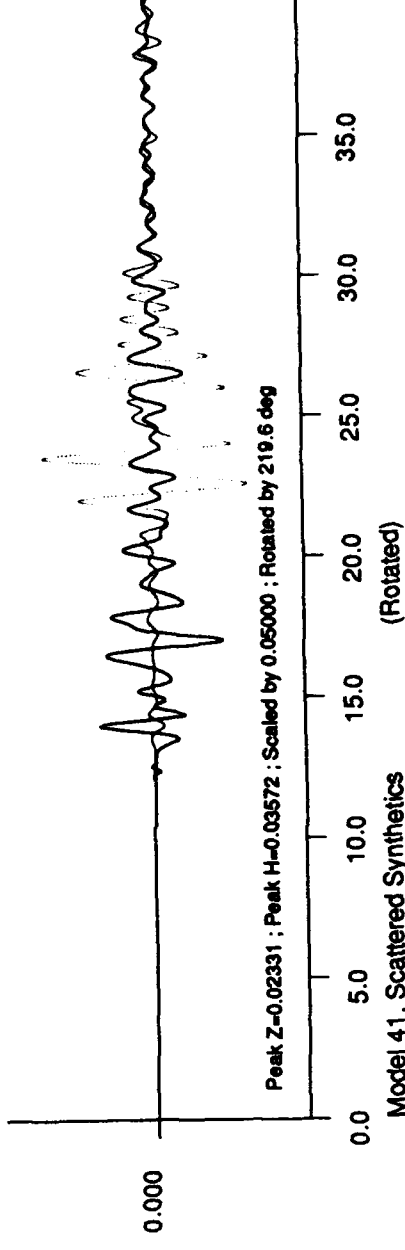
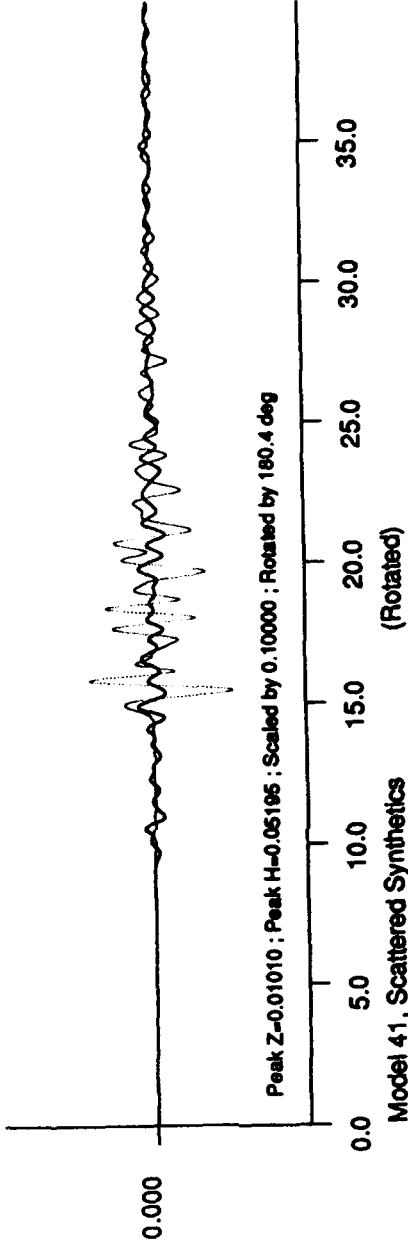
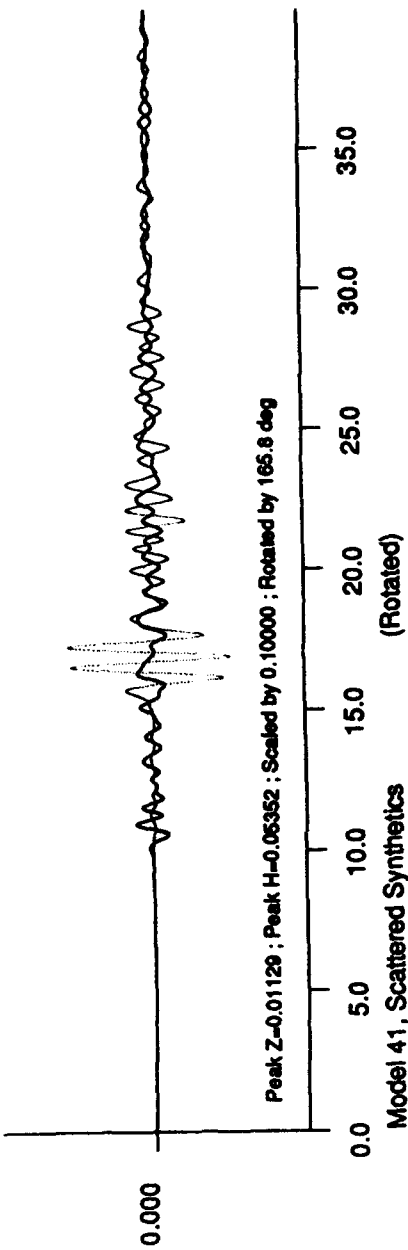
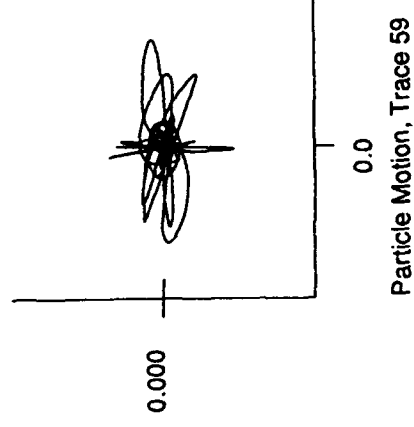
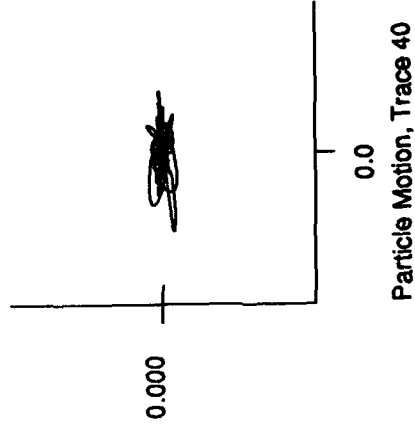
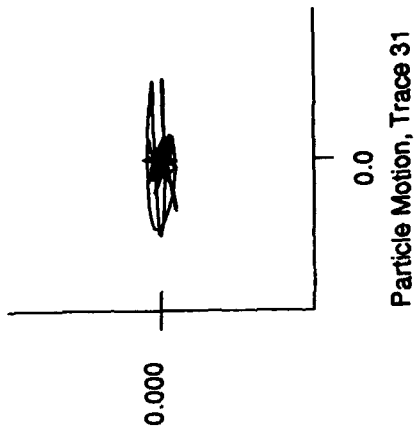


Figure 142

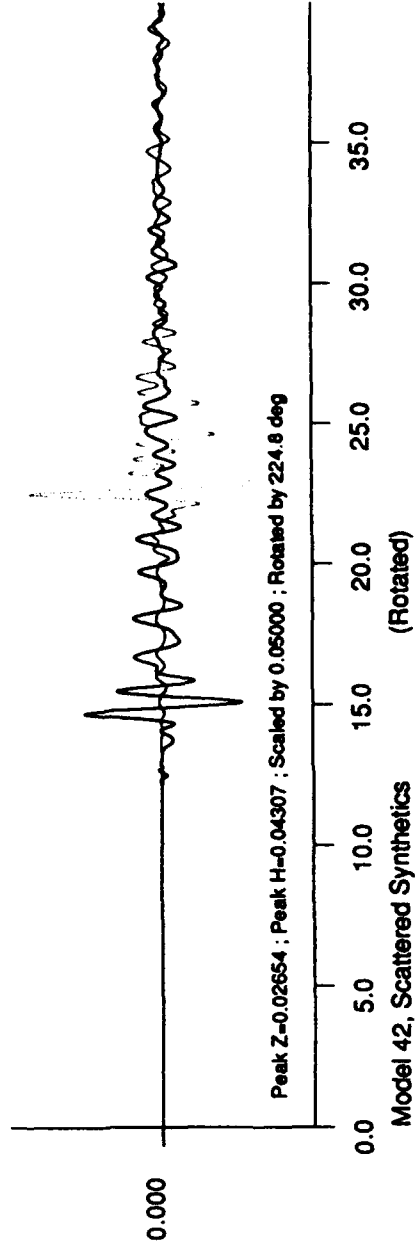
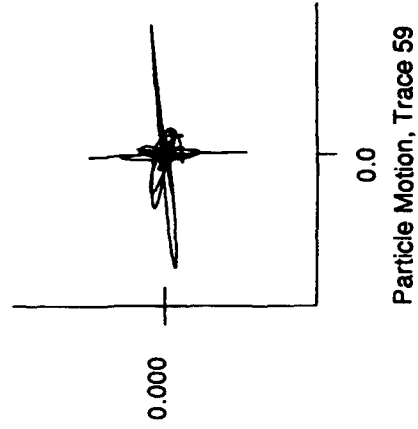
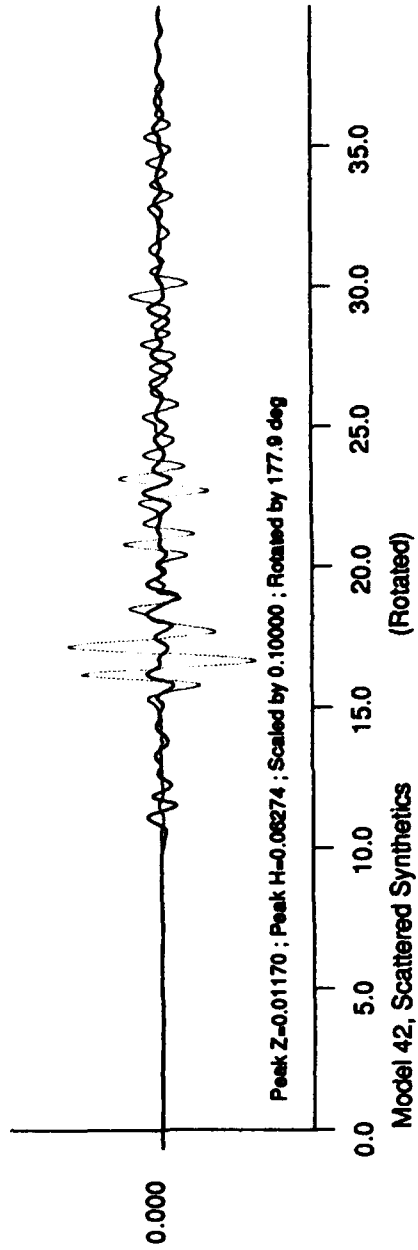
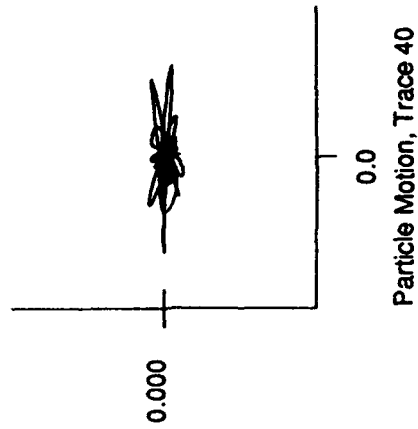
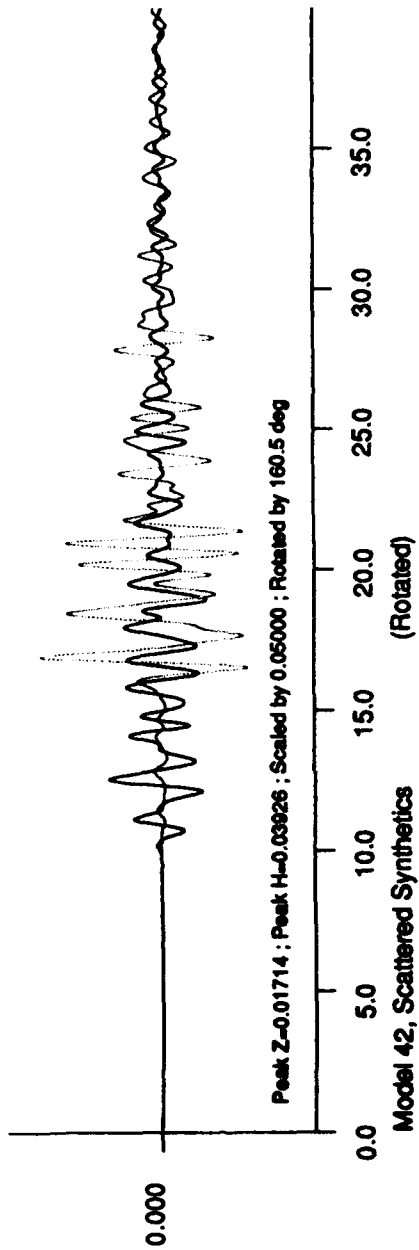
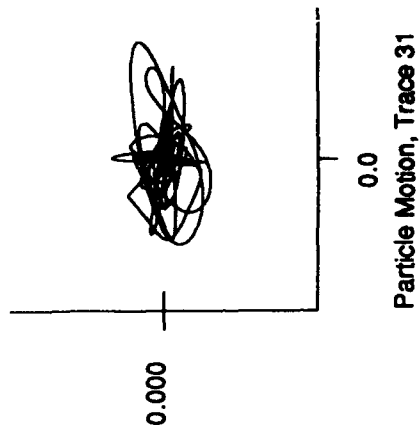


Figure 143

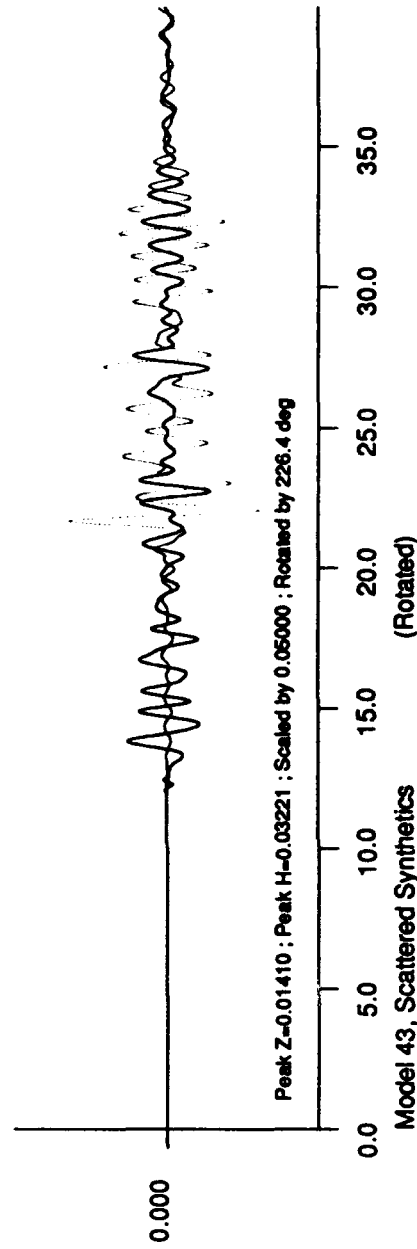
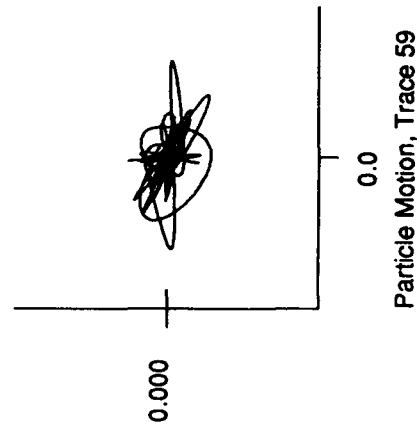
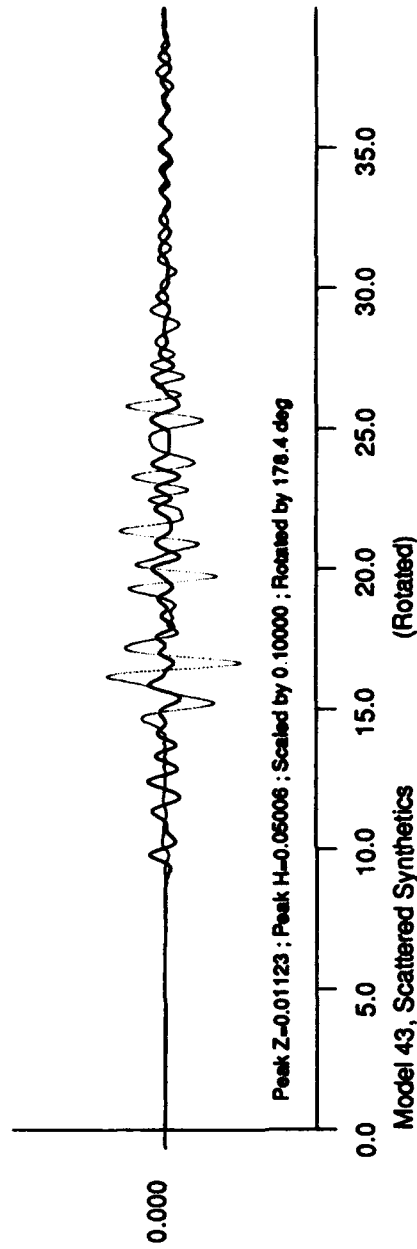
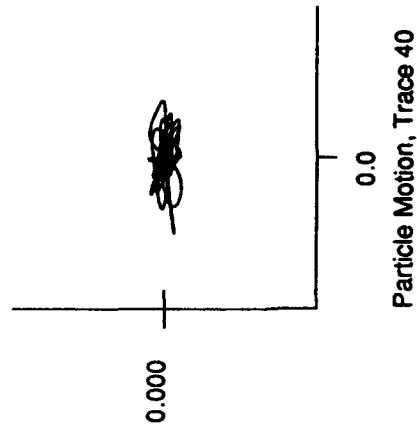
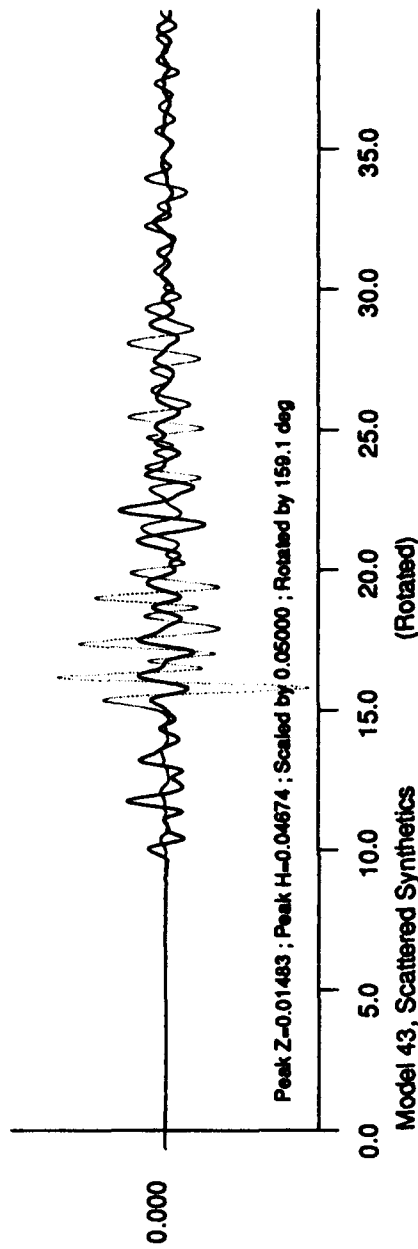
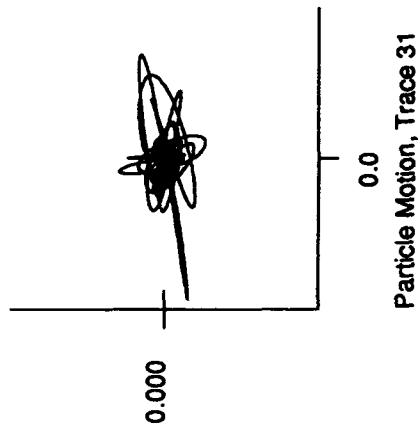


Figure 144

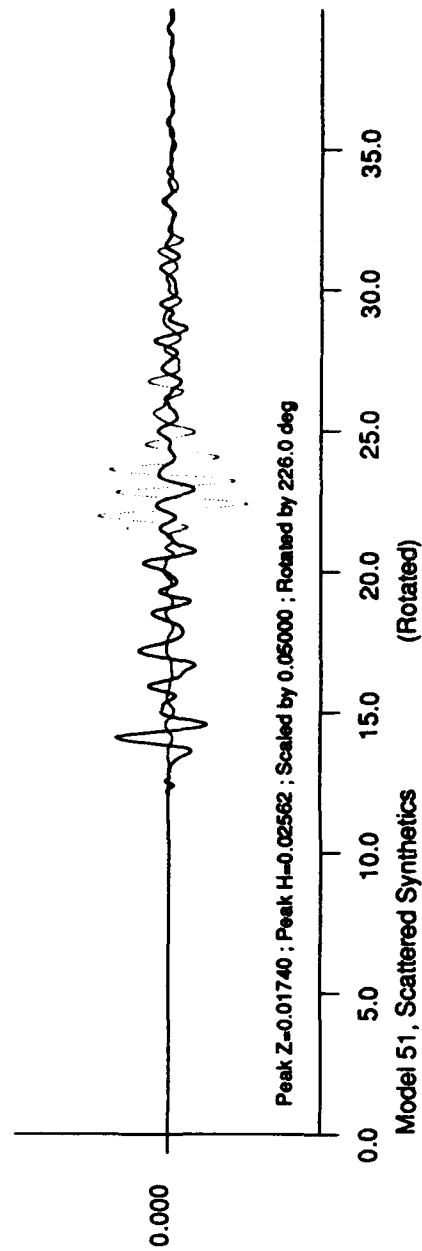
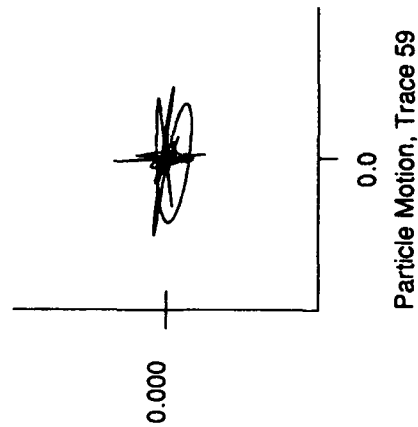
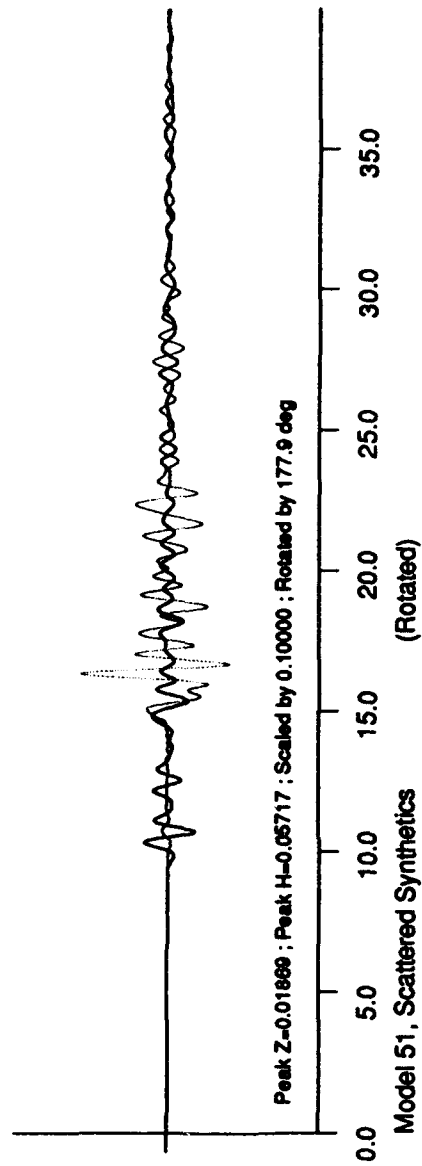
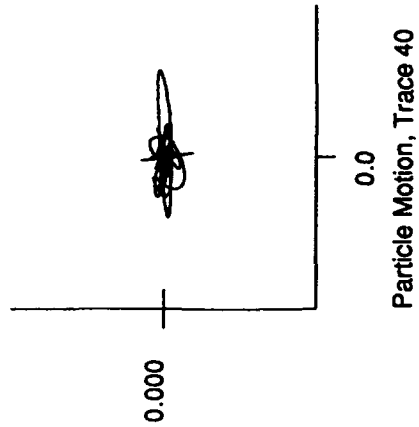
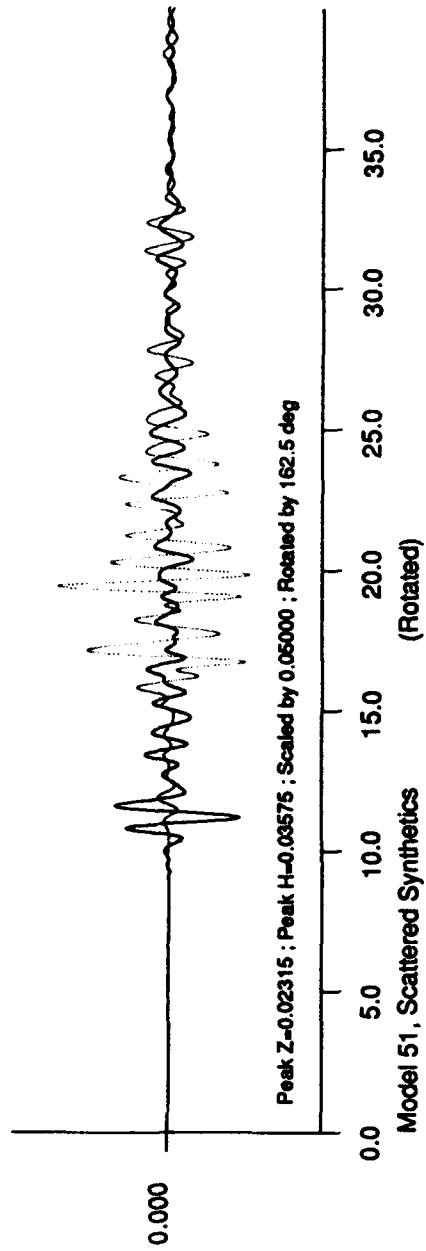
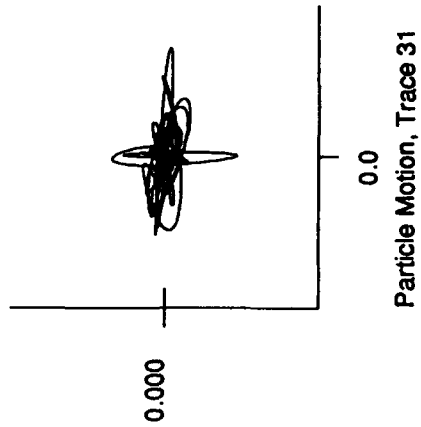


Figure 145

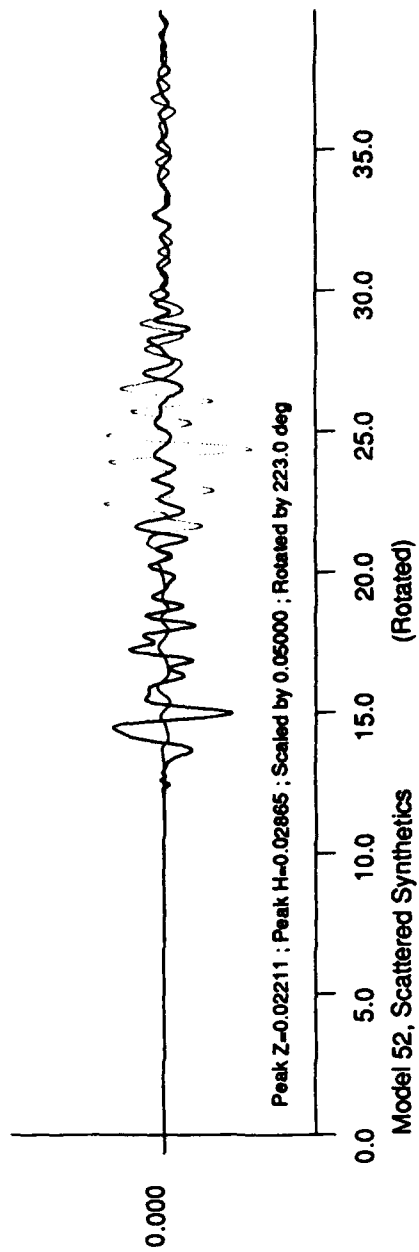
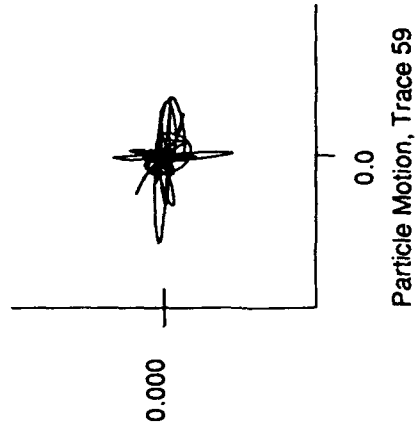
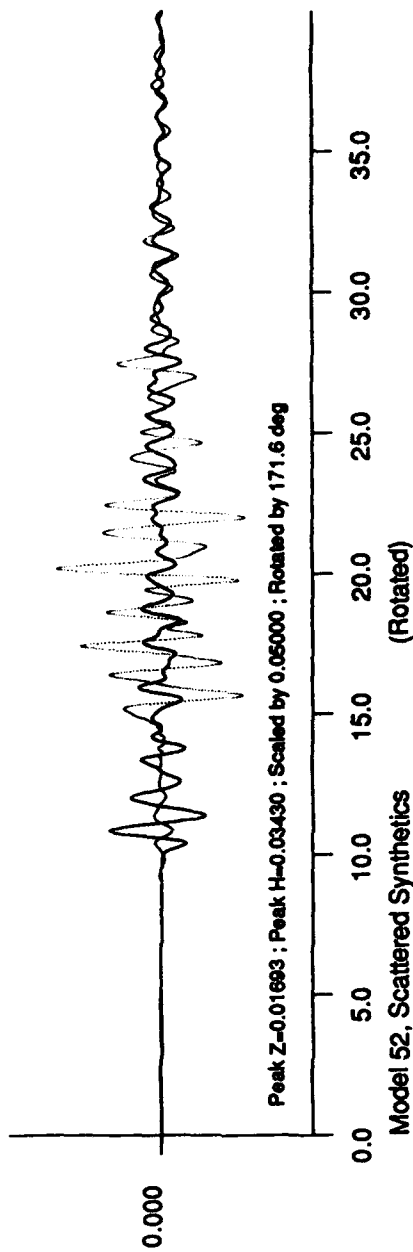
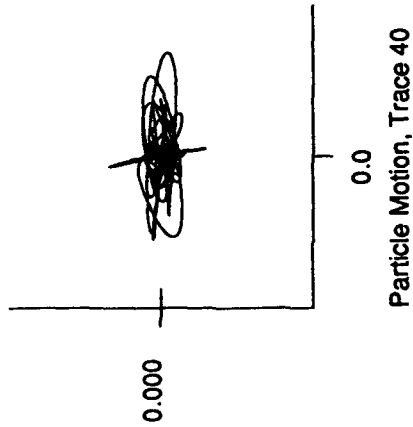
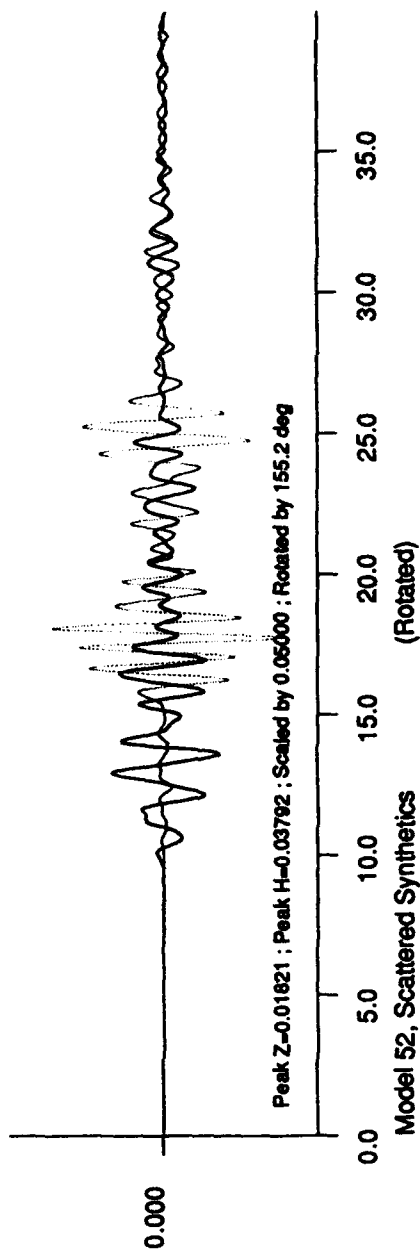
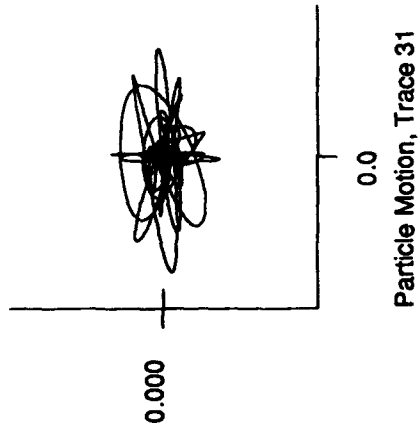
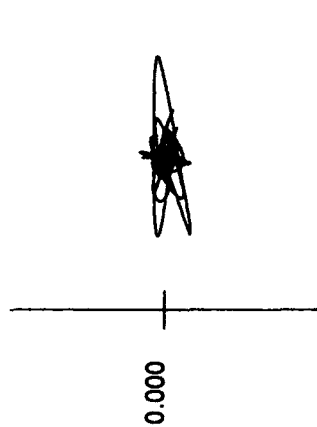
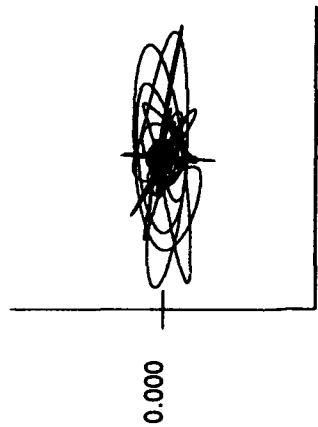


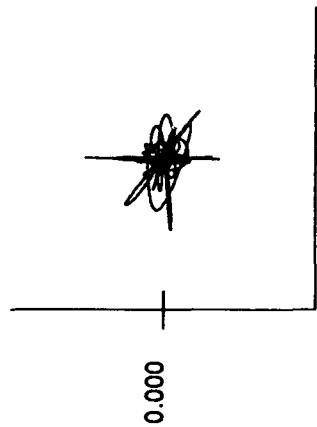
Figure 146



Particle Motion, Trace 31



Particle Motion, Trace 40



Particle Motion, Trace 59

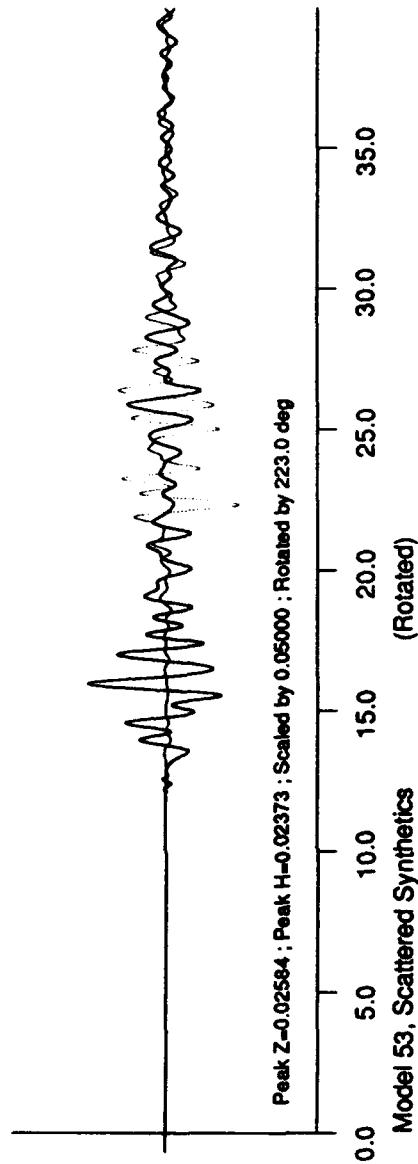
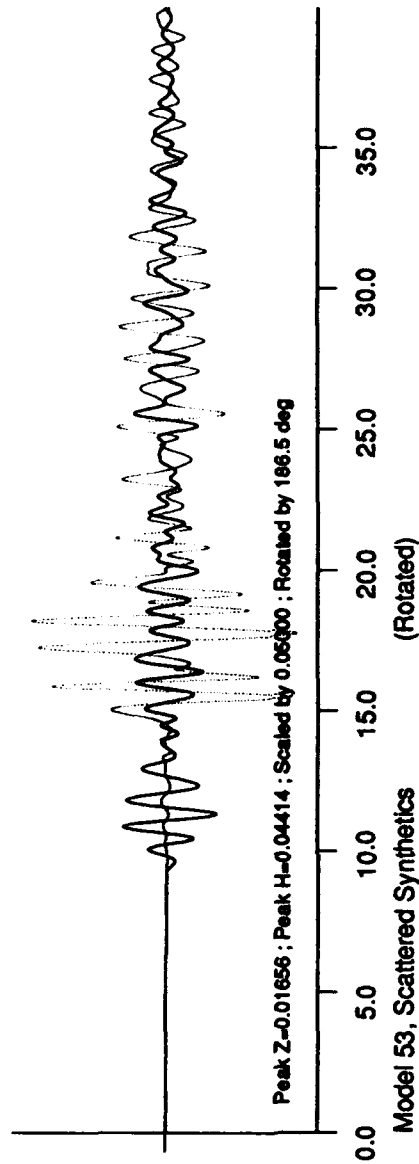
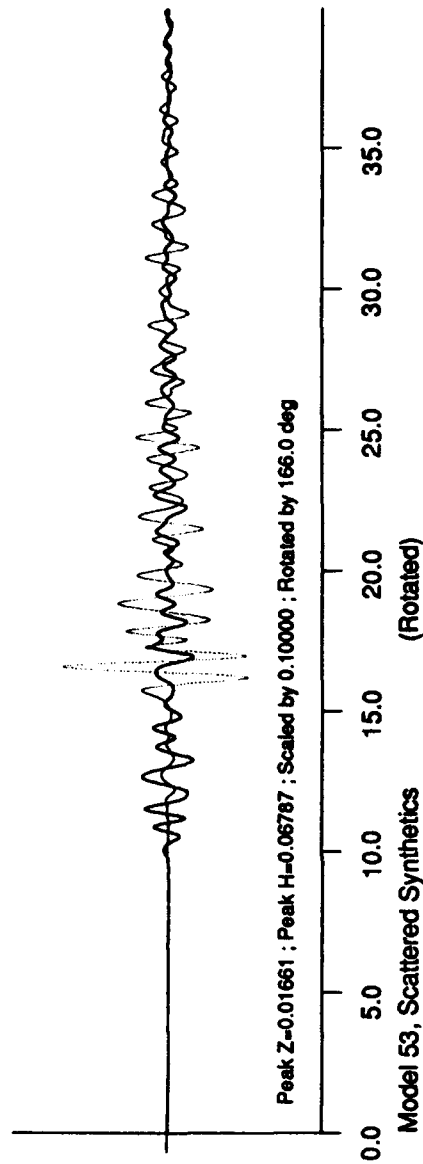
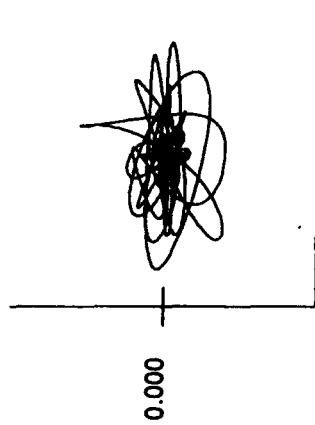
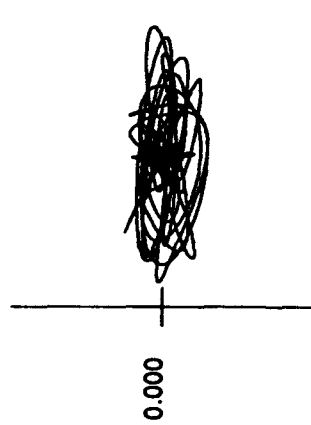


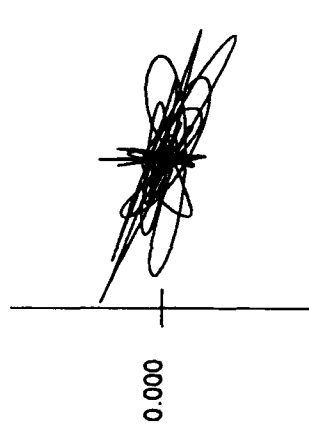
Figure 147



Particle Motion, Trace 31



Particle Motion, Trace 40



Particle Motion, Trace 59

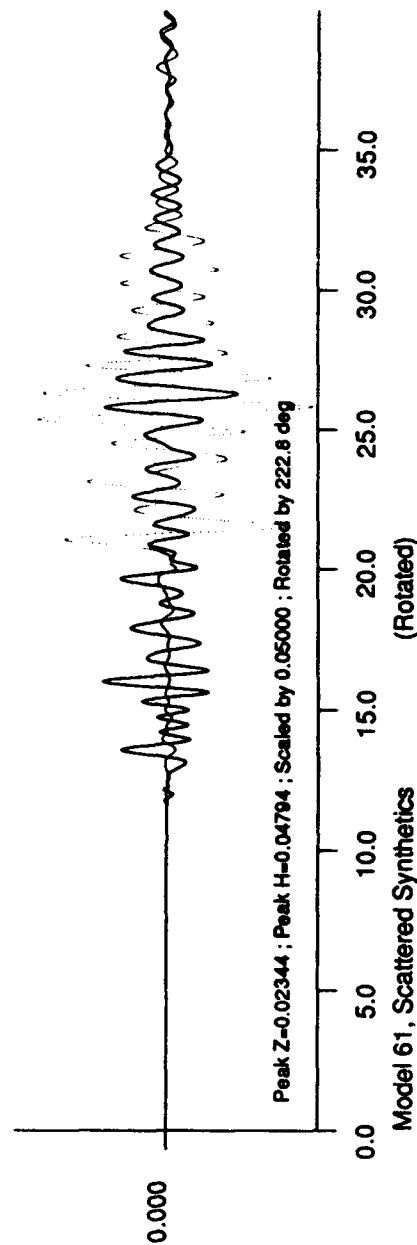
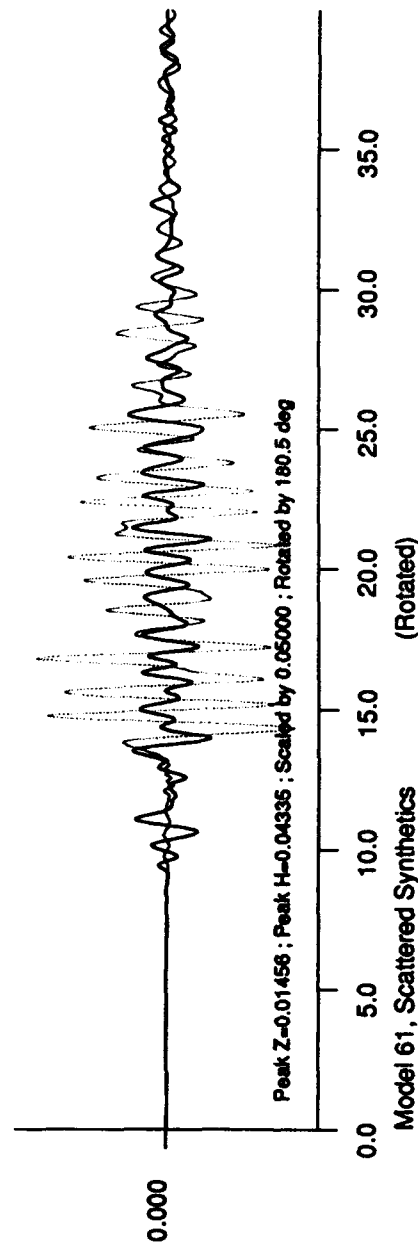
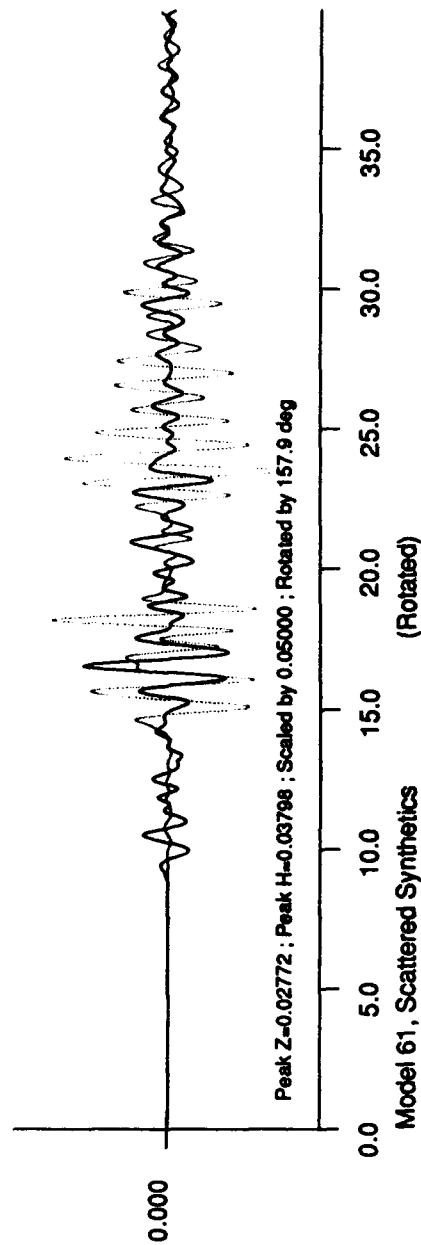


Figure 148

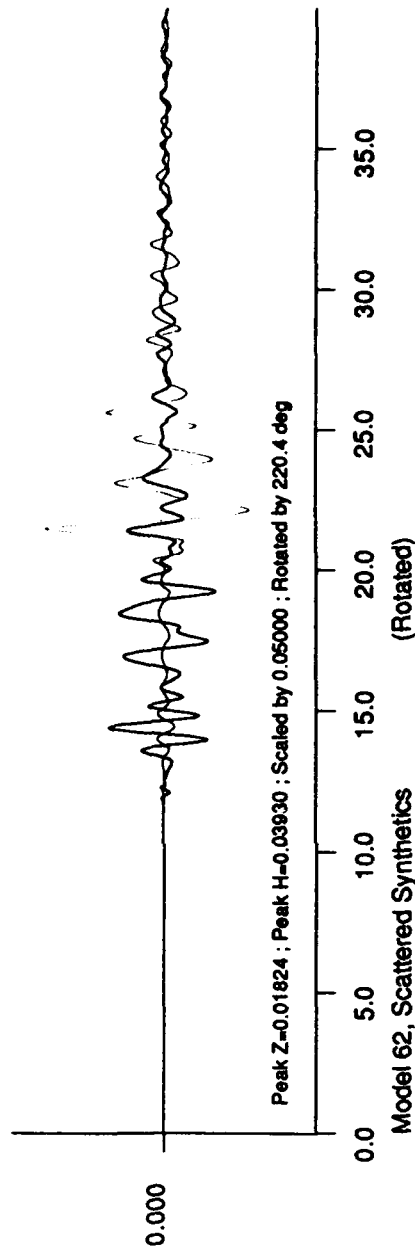
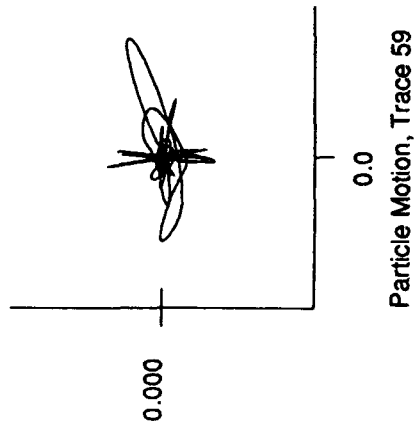
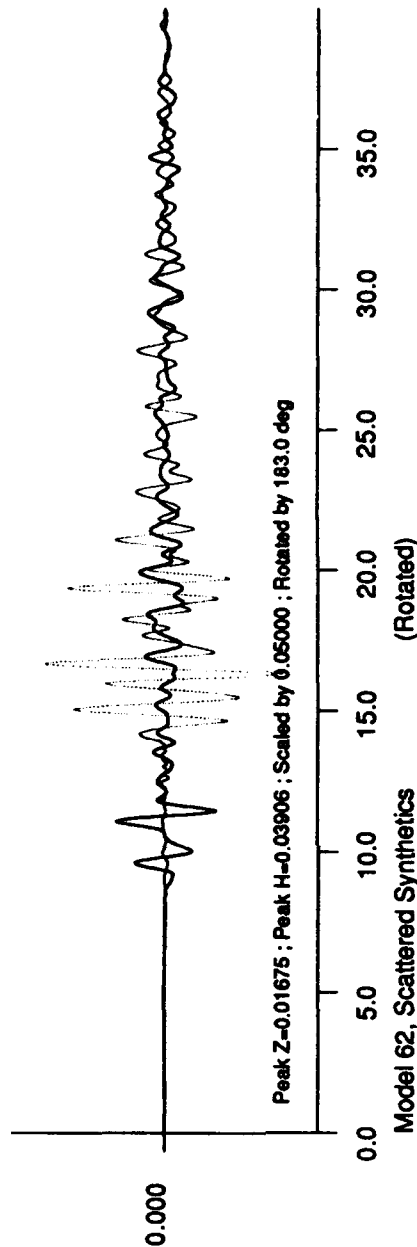
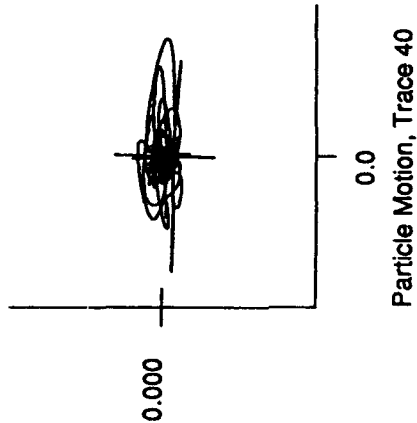
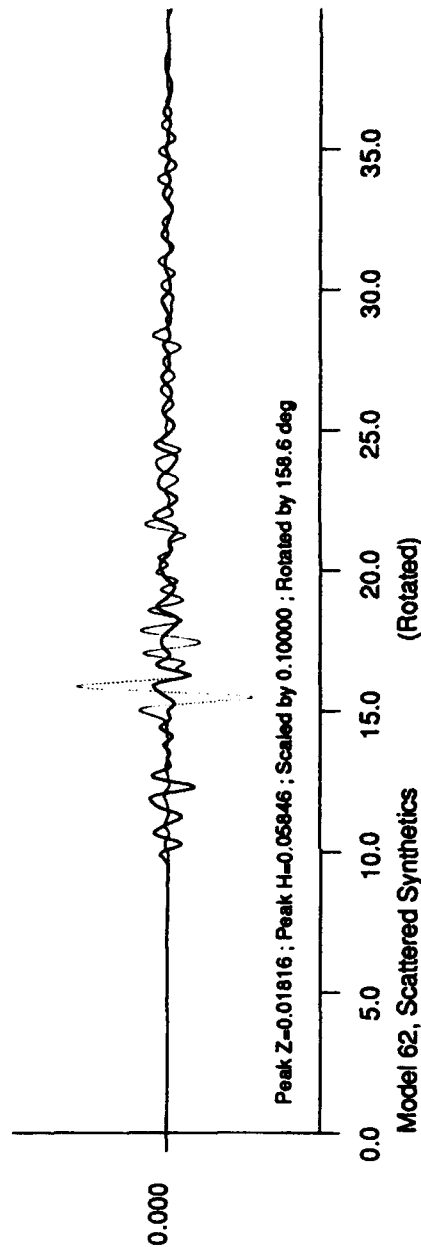
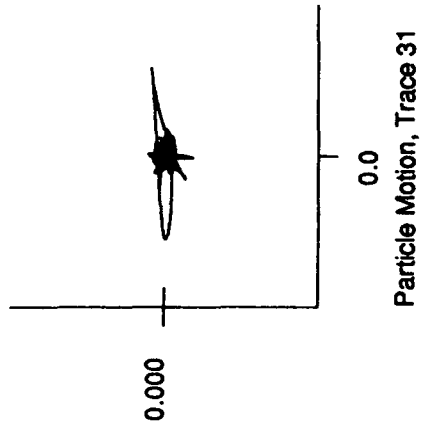


Figure 149

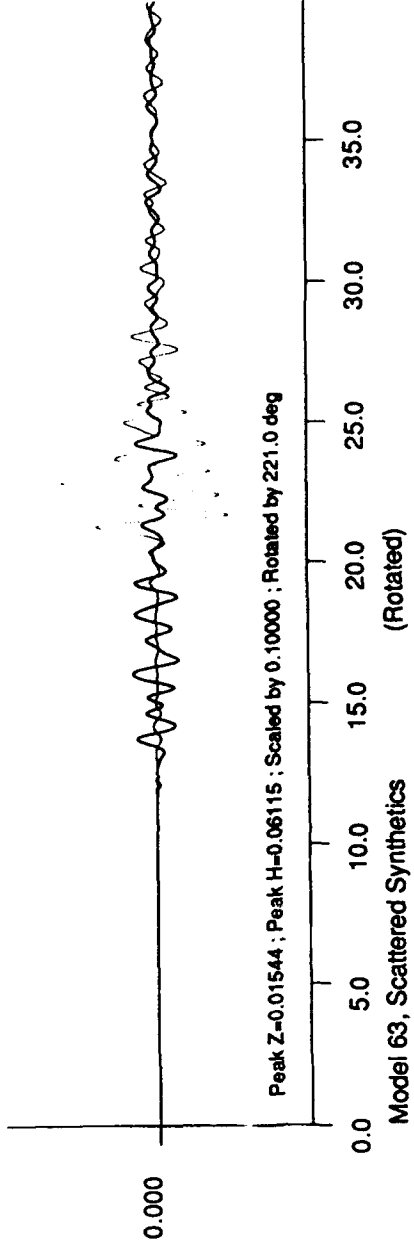
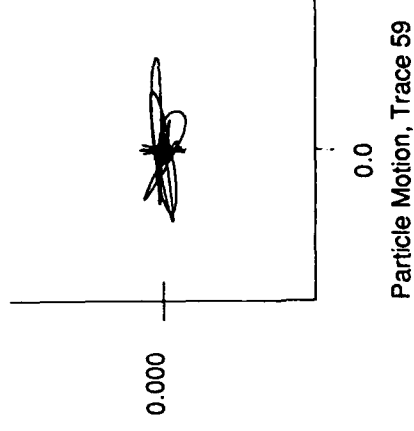
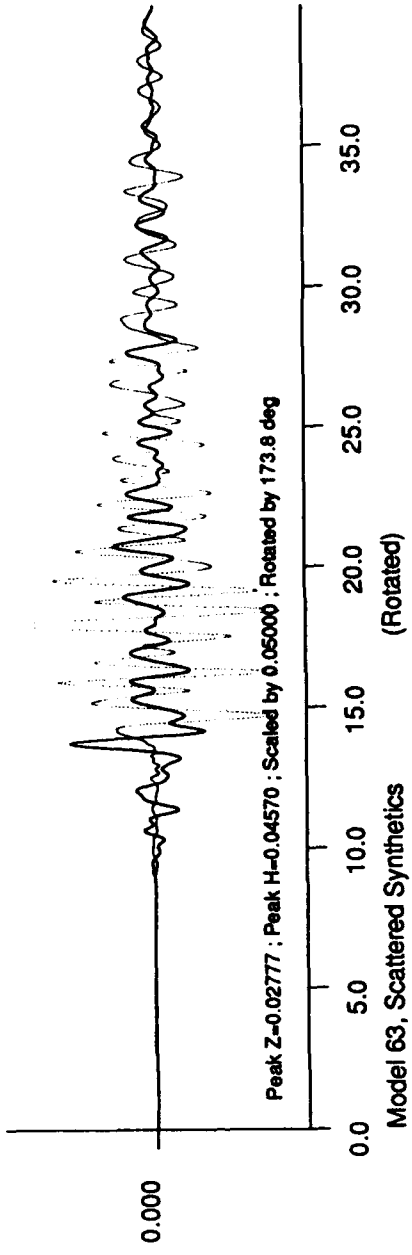
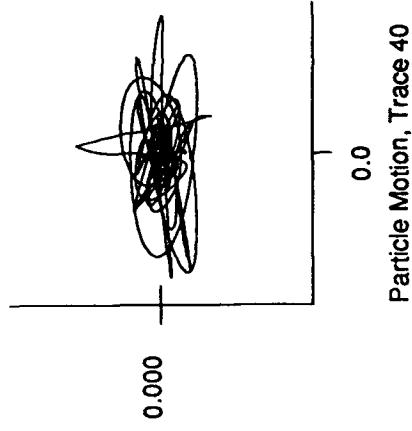
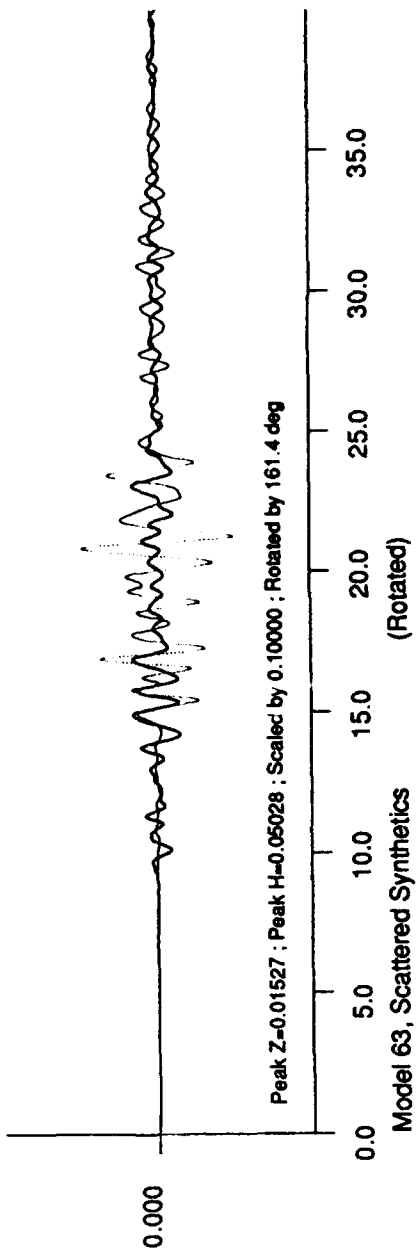
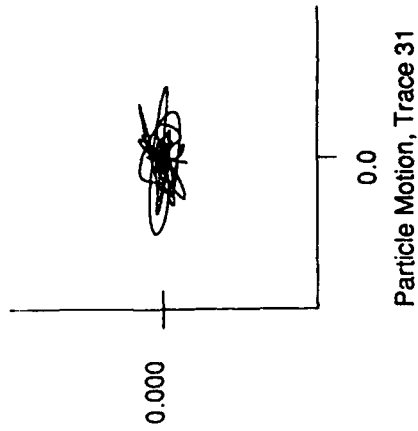


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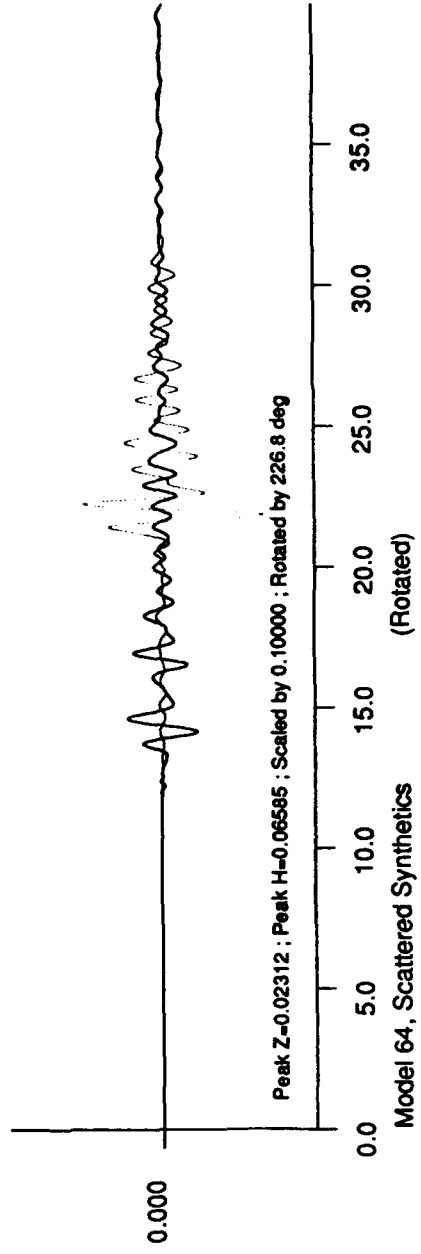
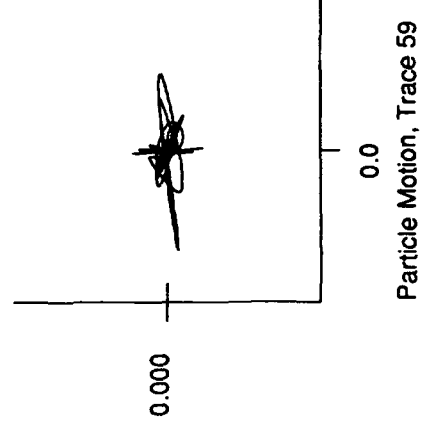
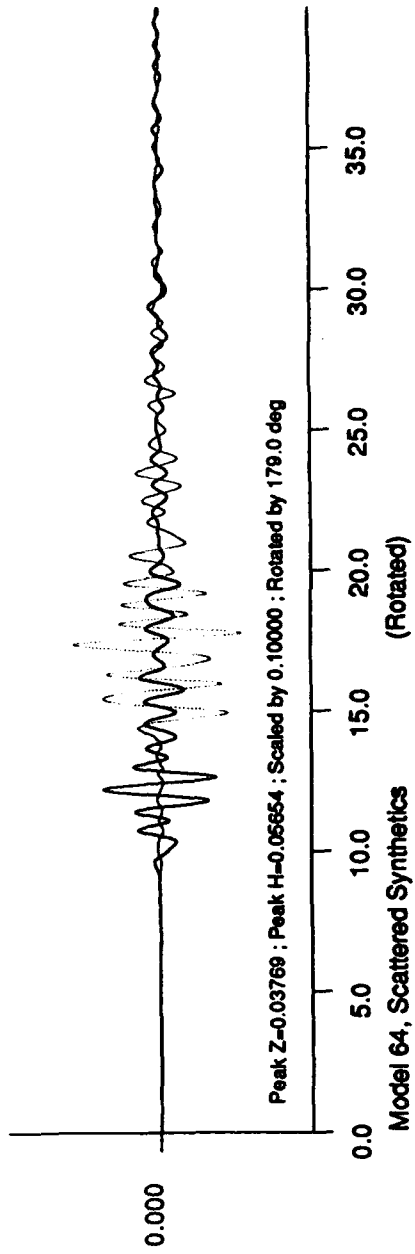
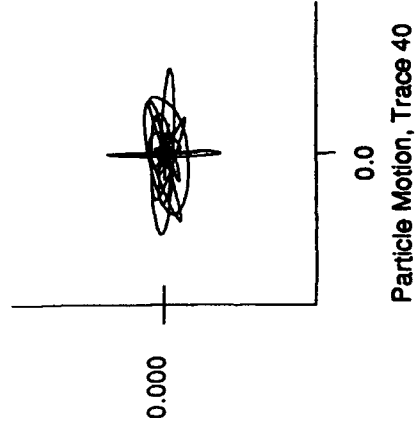
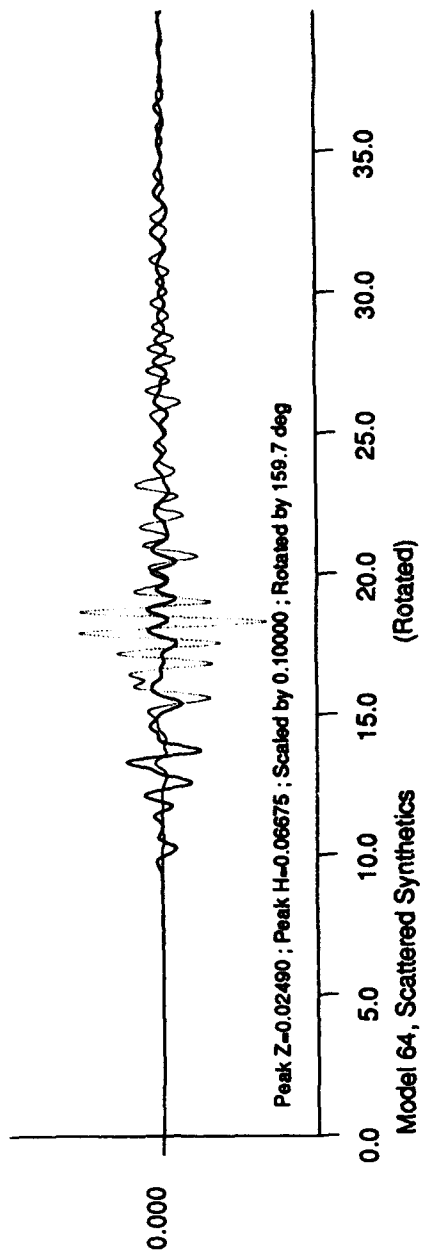
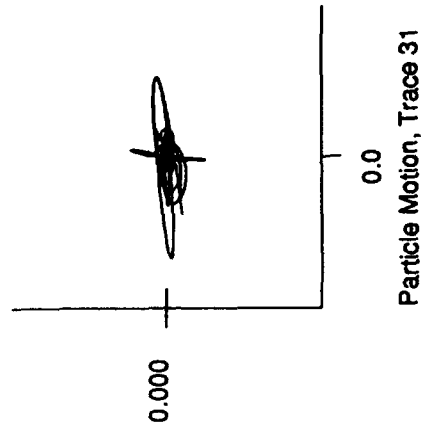


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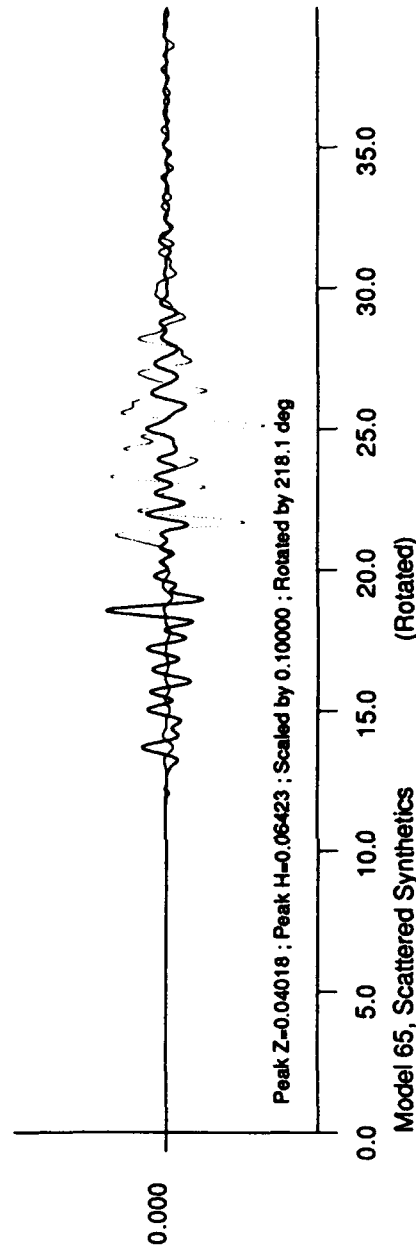
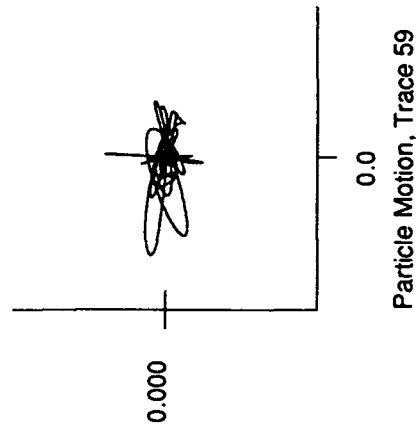
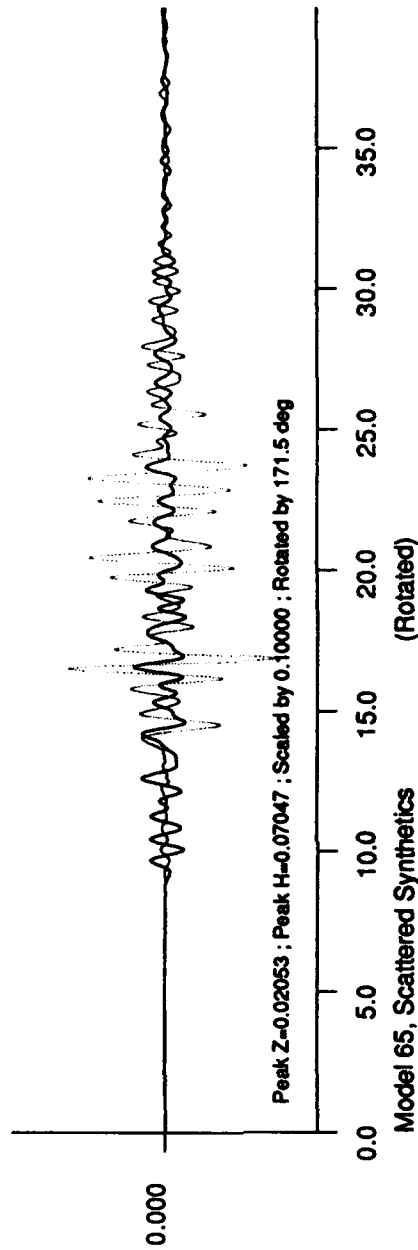
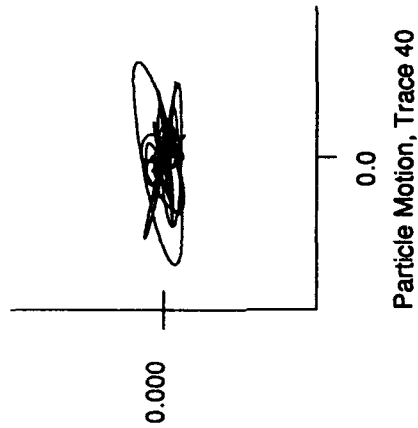
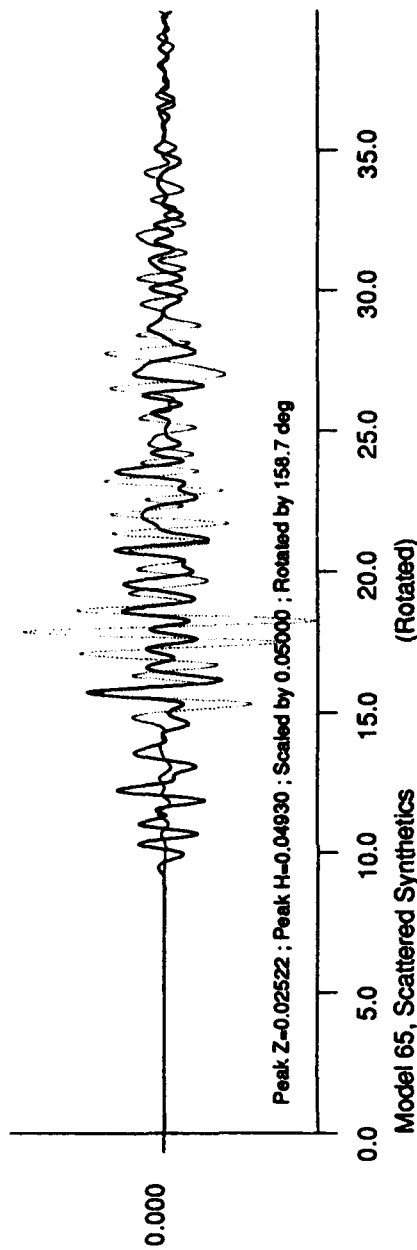
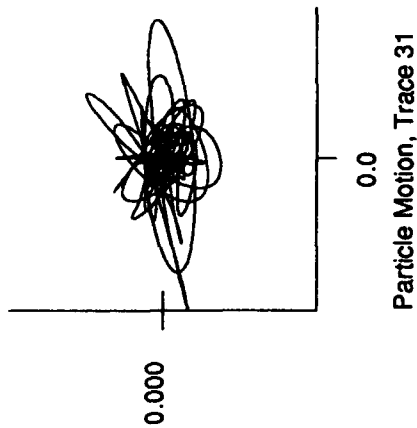


Figure 152

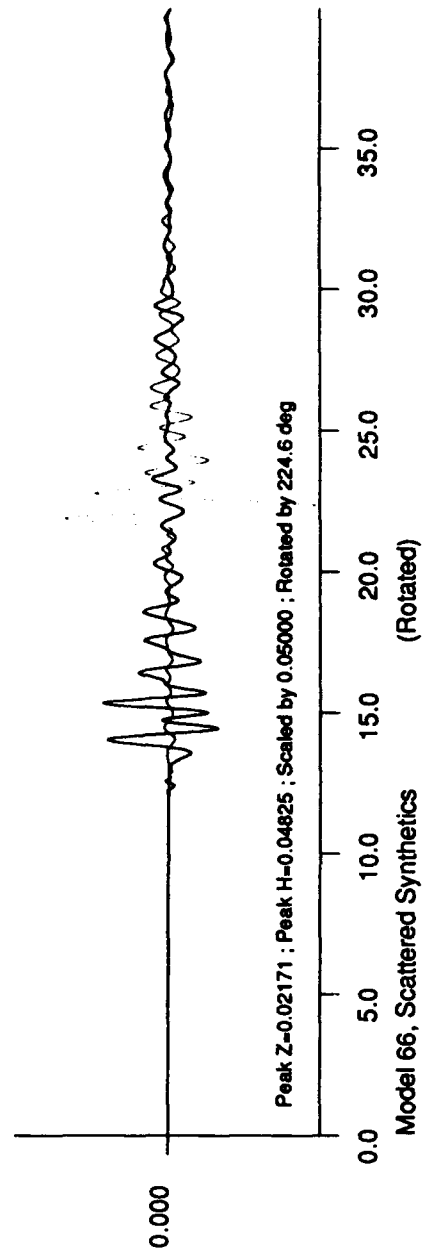
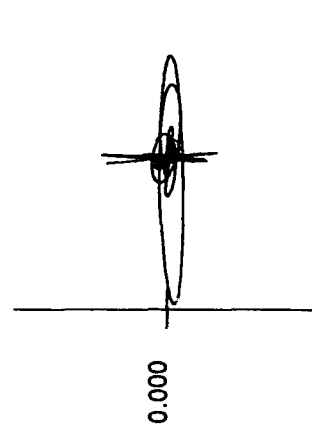
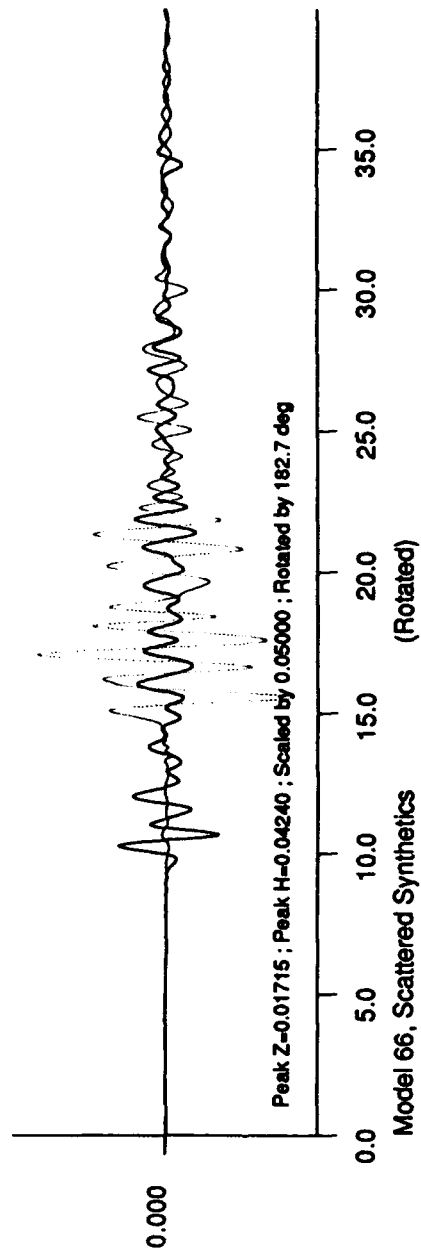
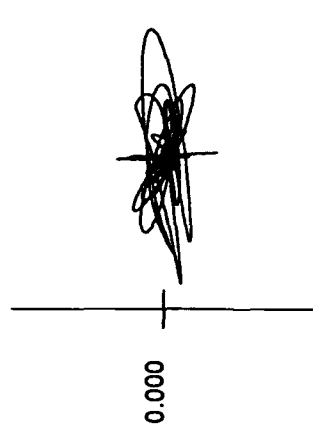
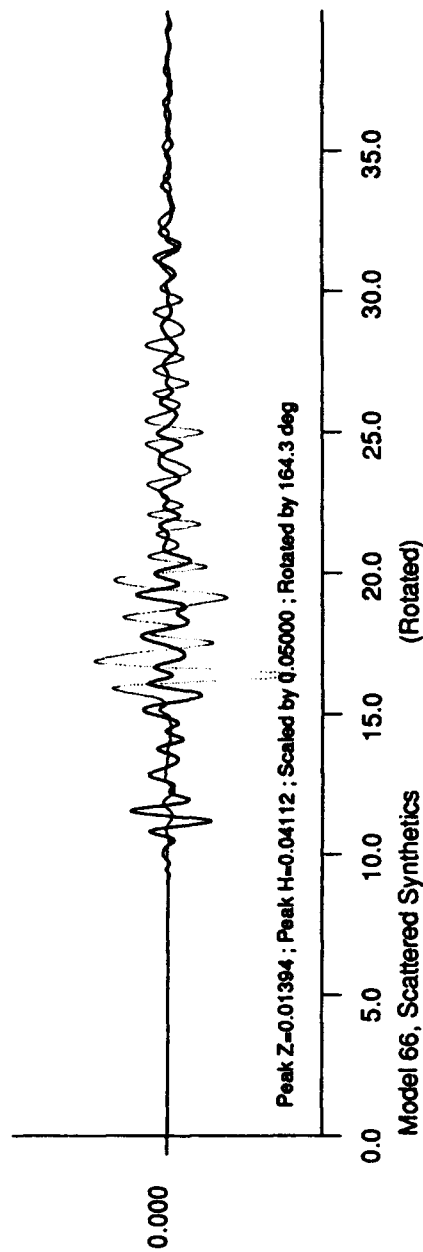
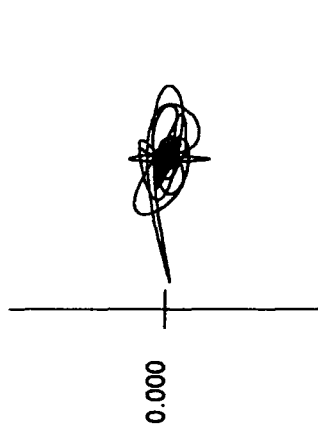
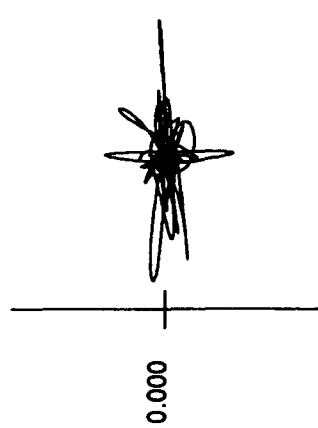
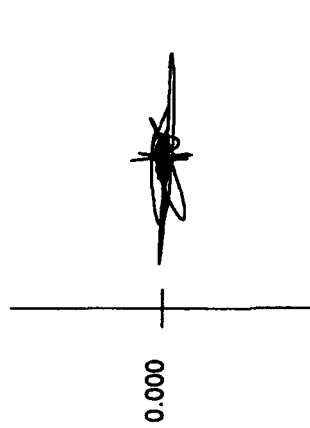


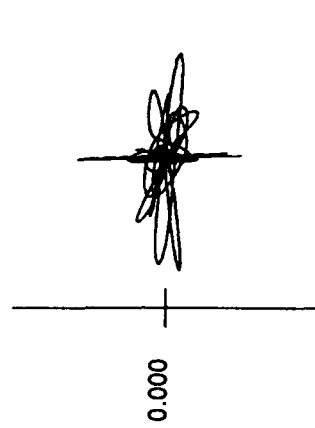
Figure 153



Particle Motion, Trace 31



Particle Motion, Trace 40



Particle Motion, Trace 59

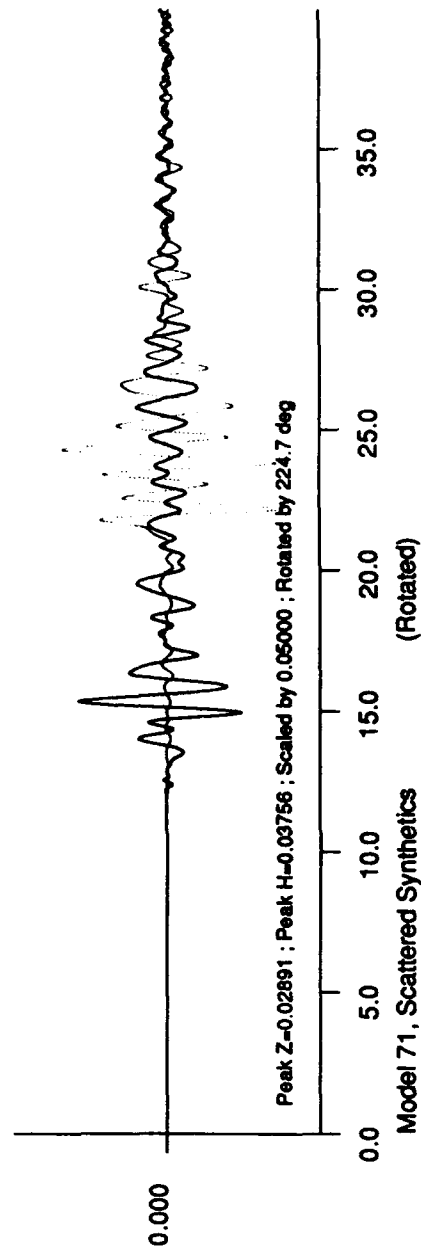
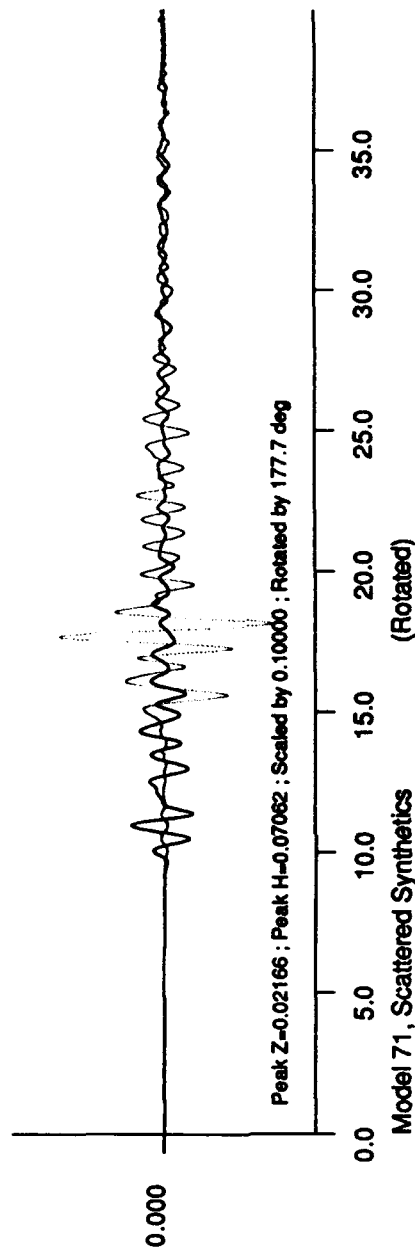
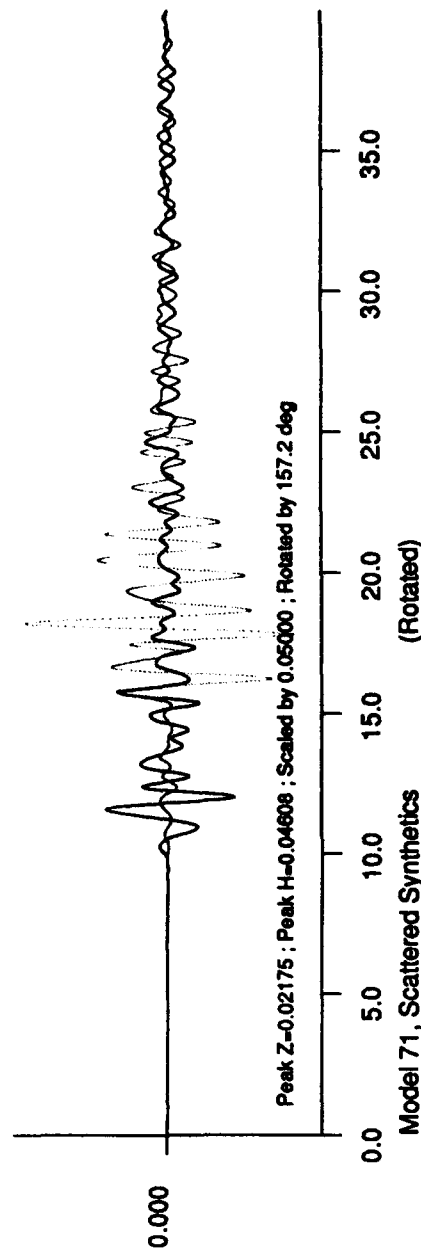


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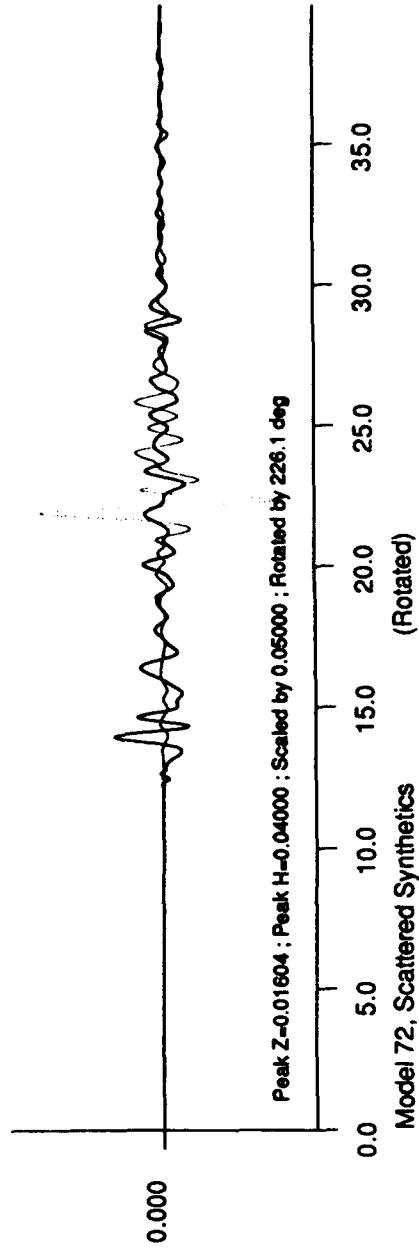
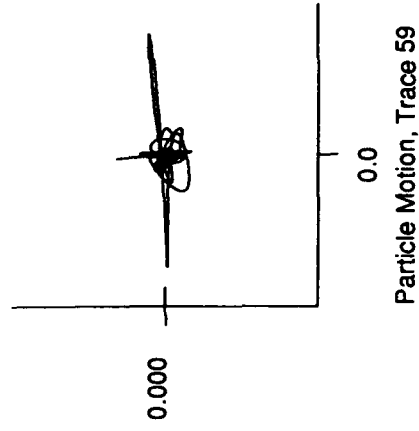
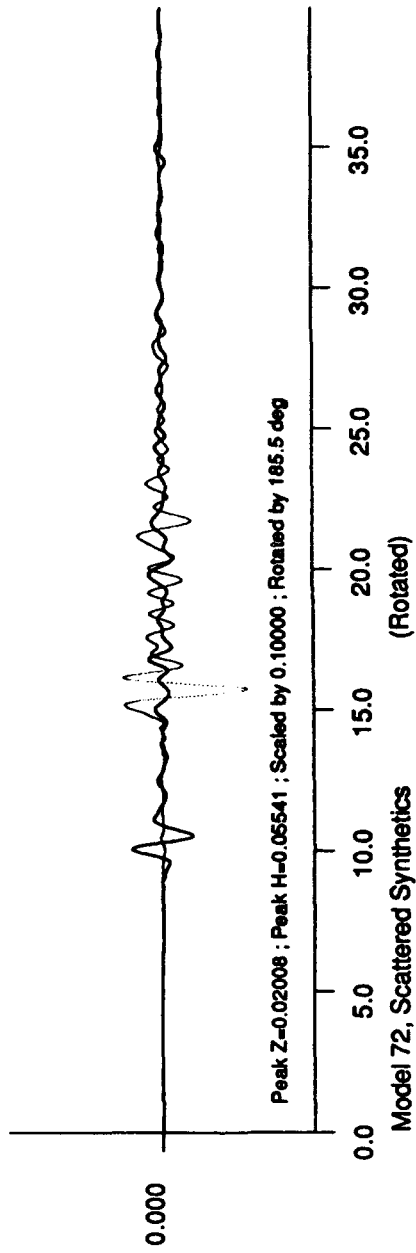
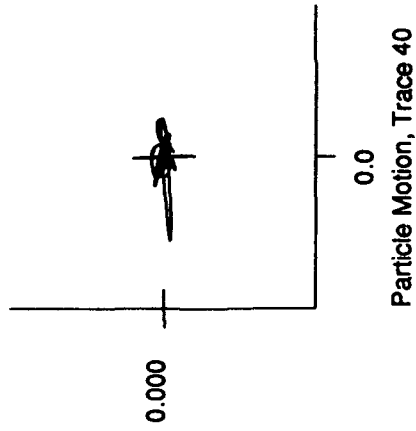
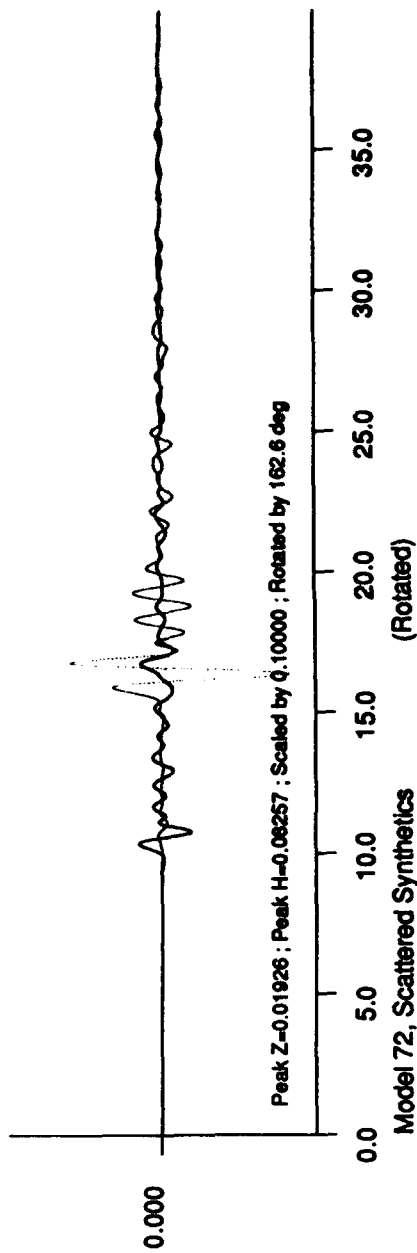
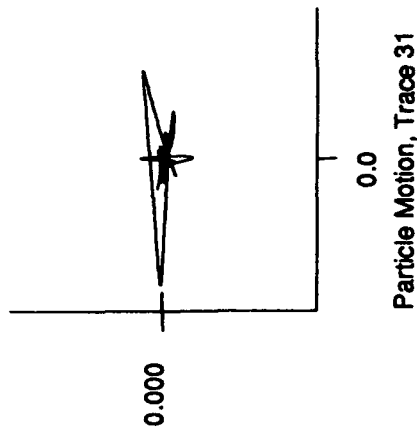


Figure 155

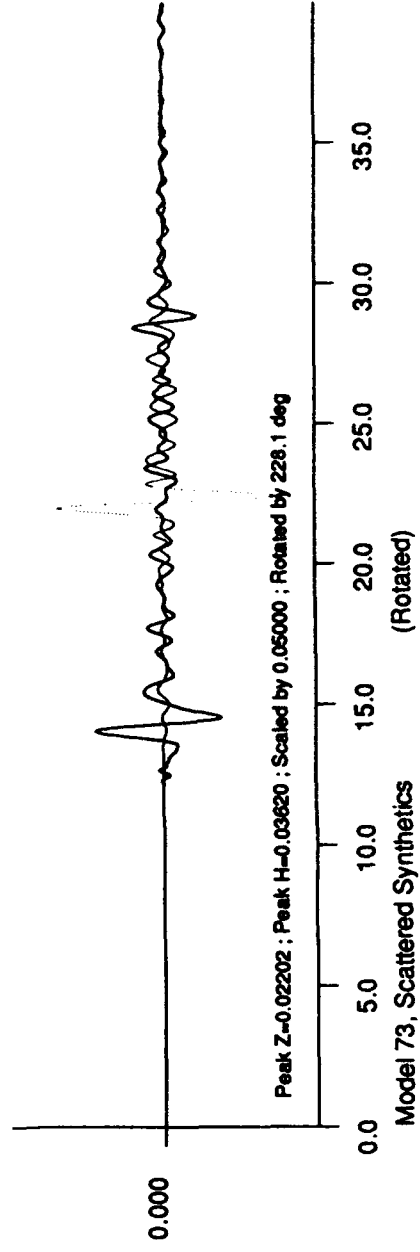
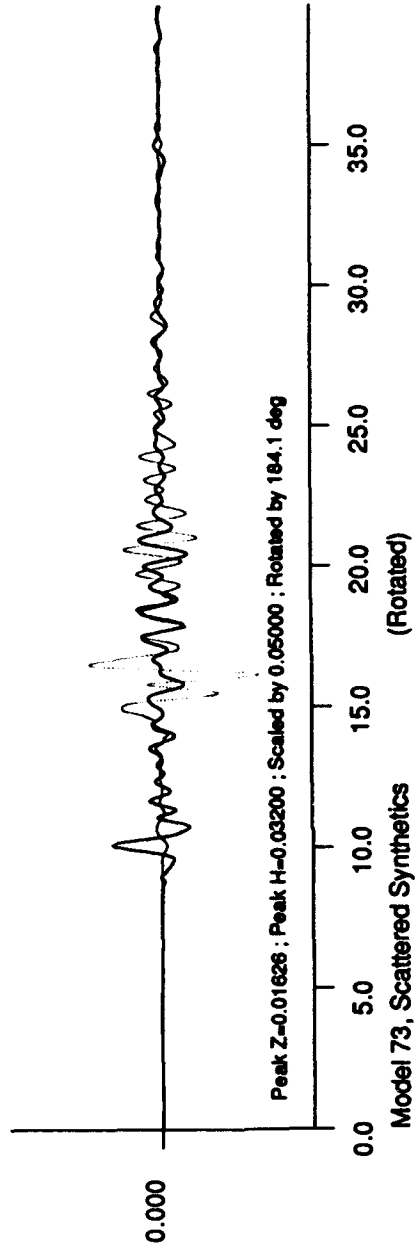
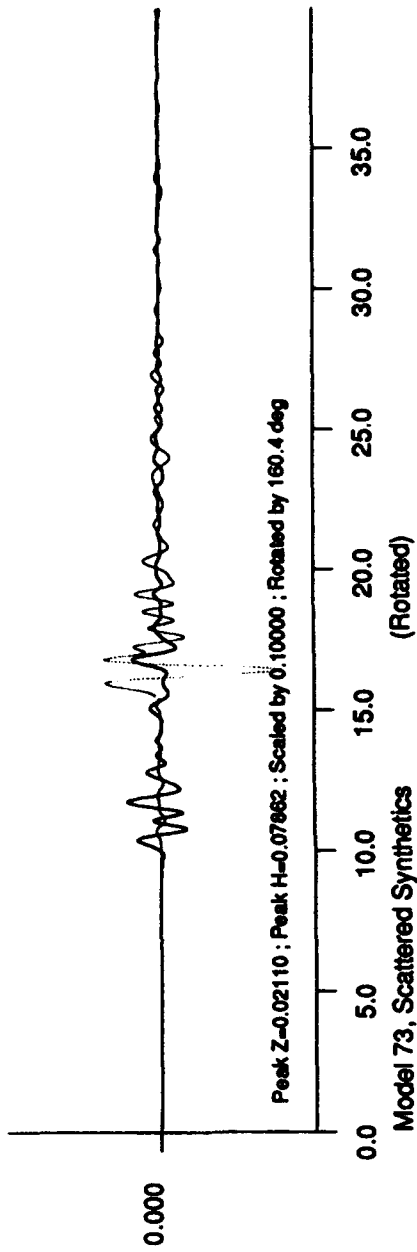
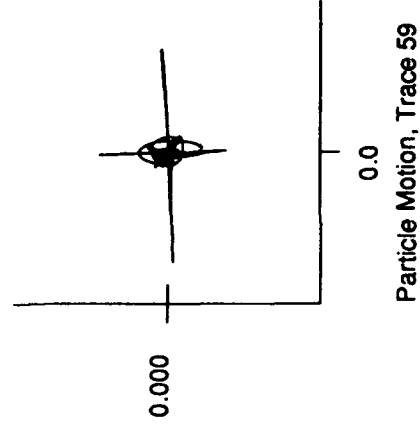
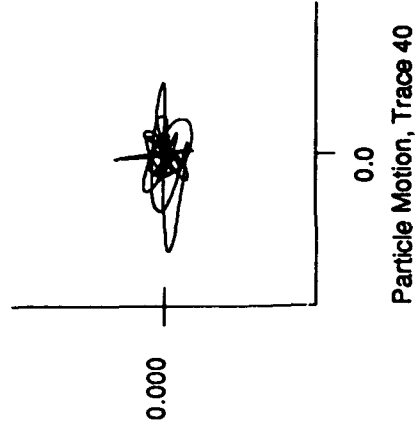
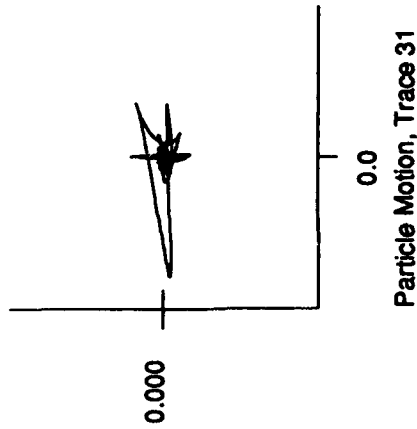


Figure 156

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